CHAPTER C.4
HYDRODYNAMIC MODELS OF SUBPROVINCE 2

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4.1 Barataria Hydrodynamic Model

4.1.1 Introduction

This Chapter discusses ongoing modeling efforts that support the Davis Pond project modifications near-term critical feature of the tentative selected plan. Louisiana State University (LSU) researchers gained experience with TABS-MD (RMA 2, RMA 4) models developed by Mr. David Elmore, P.E., of the U. S. Army Corps of Engineers, New Orleans District (USACE) in the course of preparation by the State of Louisiana to operate the Davis Pond Diversion structure. The Barataria model was developed to predict salinities at target locations in the Barataria Basin down estuary of this through-the-levee diversion. This structure was ready for limited service in February 2002. Two variants of the TABS model ("with marsh" and "no marsh") have been described in some detail in USACE (2000, 2001) and Moffatt & Nichol (2000), and in the Calibration and Validation CD.

TABS-MD is the latest version of a suite of computer simulation models developed at the USACE Waterways Experiment Station in Vicksburg, Mississippi. All TABS modules, whether for constituent or sediment transport, rely on a central two-dimensional, finite-element representation of estuarine and fluvial hydrodynamics (Thomas and McAnally 1990). The model domain includes the lower two-thirds of the Barataria Basin as well as a portion of the adjacent continental shelf (Figure C.4-1). The USACE developed "with marsh" and "no marsh" versions of Davis Pond salinity prediction models. Both are set to provide output salinity time-series at six points in the lower Barataria Basin arrayed along two target lines running east-west across the head of Barataria Bay and across the widest part of Barataria Bay (Figure C.4-2). The three northern points define the "5 ppt line," while the southern points are on the "15 ppt line," also called the "Ford Line." Most results presented here show salinity at these six locations on a common Y-axis, with time in days or hours on the X-axis. The TABS model suite can be used to predict numerous other properties of the estuarine system, but the initial focus of the LCA Ecosystem Model was on salinity at the target points.

The USACE models were delivered to the Louisiana Department of Natural Resources (LDNR) as calibrated and validated products. Output from these models was used by the USACE to create simple nomographs designed to guide a structure operator in determining how long to transfer water from the river to the basin at a given discharge to achieve a particular level of salinity reduction at a particular location (USACE 2001).

LSU was successful in reproducing the USACE calibration and validation runs. LSU was then asked by LDNR to make some additional tests to ascertain model behavior under conditions likely to occur during operations. This work was completed in early 2002, but reports generated were available only on the internet (www.tabs.lsu.edu). Later, some of the same research team at the LSU Natural Systems Modeling Group was asked by Dr. Robert Twilley at the University of Louisiana at Lafayette (UL Lafayette) to use the same USACE model (no marsh) to generate salinity predictions for additional diversion scenarios developed in the early phases of the Louisiana Coastal Area study (LCA). The following section summarizes information about the USACE model from the earlier LDNR study and describes the preliminary work completed under the LCA.

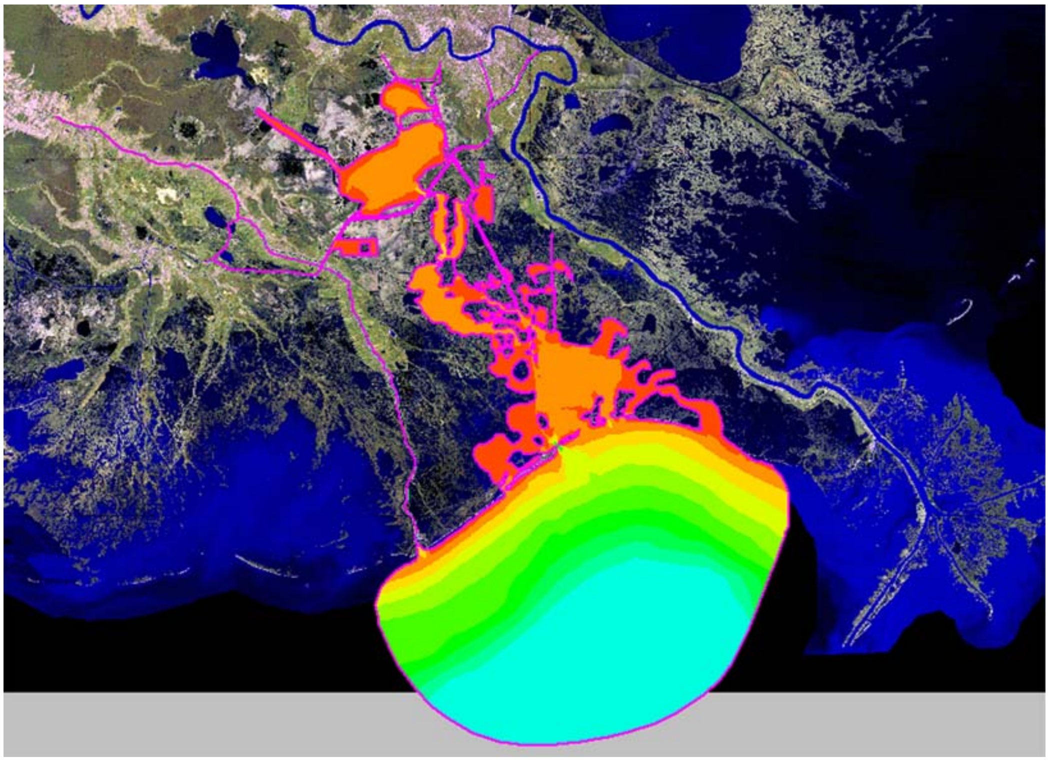

Figure C.4-1 TABS-MD Model Domain as Developed by the USACE New Orleans District

4.2 Idealized Wind and Tides

4.2.1 Introduction

The relevant objectives of the earlier work conducted for the LDNR were focused on the "no marsh" version of the Barataria model. These were divided into two phases. The first phase addressed model behavior under idealized conditions with a monotonic tide and constant wind speed and direction. The second phase examined model behavior under more realistic conditions where the model was driven by real tides and winds. The use of the model in the LCA project called for two key model-related objectives, listed below:

A. Implement a collaborative program with the Louisiana Department of Natural Resources (LDNR) and the U. S. Army Corps of Engineers (USACE) to collectively test and improve calibration of the existing USACE TABS-MD Davis Pond models.

B. Identify current limitations of the models based on, but not limited to, an initial review of the following:

a. Data used in the development of the model, including topography, bathymetry and hydrology;

b. The Moffatt & Nichol report that addresses this model;

c. Sensitivity analyses performed to date; and

d. Calibrations performed to date

Objective A. Researchers sought to develop a communication framework that would support further model development through collaborative engagement between LDNR and the USACE. LSU arranged meetings with Mr. David Elmore, the USACE modeler who created the two Davis Pond model variants (with and without marsh forms). The USACE explained that they were finished with the pre-construction work, but that they would be re-verifying after two years. Five data collection platforms (DCP) are now in place and collecting data, with more to follow.

Months of little rainfall were selected during the 1988 instrument deployment to use for calibration and validation. Although precipitation was not directly addressed, it was assumed that precipitation and evaporation were roughly equal. Mr. Elmore believes that reliance upon a single New Orleans airport source for wind data may be a serious source of error. Model runs to develop the salinity reduction nomographs did not include wind stresses as it was assumed that any wind effects would cancel out over the course of a month.

Boundary flows were assumed constant in the one-dimensional reaches at 0.6 of a selected velocity applied to the entire channel cross-section. The GIWW boundary was assumed to be no-flow. A discharge of 250 cfs was assumed for Bayou Lafourche. Much additional documentation is available in USACE (2000) and Moffatt & Nichol (2000), and in the Calibration and Validation CD.

A web site, www.tabs.lsu.edu, has been established where model results from any source can be displayed. LSU was able to reproduce all results provided to LDNR by the USACE and has found the no marsh model to be very stable and forgiving.

Objective B. Researchers identified limitations of the models that might affect their utility for operations support. Based on discussions with LDNR officials, LSU focused on those factors that were likely to be most important to using the models in support of Davis Pond operations.

A decision was made to concentrate on the “no marsh” model. The “with marsh” model currently runs so slowly and requires acceptance of so many additional assumptions that it was set aside until the limitations of the “no marsh” model were better understood. The lack of good topographic information was of more concern than potential problems with the wetting and drying approach used in TABS (“marsh porosity”). The “with marsh” model was used only to estimate the direction and magnitude of the salinity error introduced by not including the marsh.

The bathymetry of the Davis Pond models provided by the USACE is relatively coarsely represented; however, the “no marsh” model still has 11,368 nodes while the “with marsh” version has 23,845. Introducing the new nodes required to create a more faithful representation of the geometry, even if high-resolution bathymetry were available, would incur a significant computational load that may not be warranted for the immediate purpose. LSU has checked the bathymetry to ensure that it is reasonably correct, given the limited spatial availability of recent high-resolution bathymetry, and the absence of reliable topographic information within the model domain.

Moffatt & Nichol (2000) pointed out the problems associated with using out-of-date bathymetry given the dynamics of land-loss, but it is not believed that this will be a critical source of error in predicting salinity response at the open water target locations (Figure C.4-2).

Hydrodynamics and salinity are run sequentially in separate programs under the TABS system. Each model run, has two stages, with hydrodynamics executed by RMA 2, followed by salinity in RMA 4. The Moffatt & Nichol (2000) report focused exclusively on the hydrodynamics, and found the USACE model to be reasonably calibrated with respect to water level. Accordingly, LSU was asked to look primarily at the salinity model. A series of sensitivity analyses were performed, having been identified as crucially import. These analyses are discussed in detail in the following section.

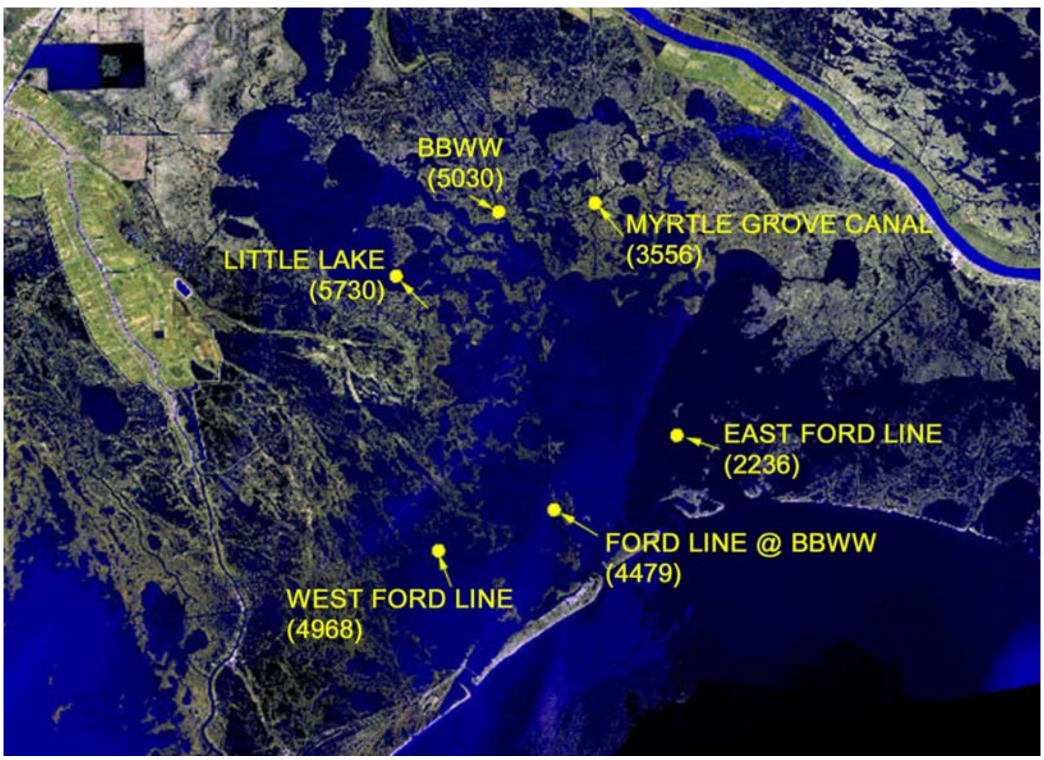

Figure C.4-2 Locations of 6 salinity output points in the lower Barataria Bay. Numbers inside the parenthesis indicate node numbers used in the "No-Marsh" model.

4.2.3Sensitivity Analyses

All analyses were conducted on the "no marsh" model; and unless specified otherwise, a standard model run includes a 2,500 cfs diversion at Davis Pond, 1,500 cfs each at La Reussite and Point a la Hache, a boundary salinity of 25 ppt, and a steady 5.75 mph wind from the south.

The research team prioritized the sensitivity analyses with respect to structure operation. One assumption was that it is not necessary for effective operation of the Davis Pond structure that the model predict change for more than one or two months, as it should be updated with actual and predicted environmental conditions every two weeks. In other words, if salinities are slowly dropping on the shelf because discharge of the Mississippi River is increasing through the winter and spring, or if significant rainfall takes place, these changes can be imposed rather than predicted. On the other hand, the model does need to be able to determine what the effects of a particular front passage will be in order to time an opening to low water, or explain why salinities in the target area went up or down despite any actions that were taken. The following questions were developed to direct the key issues to be evaluated by the sensitivity analyses.

1. Does the model conserve mass (flow), and does the model conserve salt?

These two questions are connected. If the hydrodynamic model does not conserve mass (flow), the salinity model cannot conserve salt. Two tests were developed. The first test was conducted on RMA 2 (hydrodynamics). A utility was developed (tabsutil.exe) that works with TABS-MD hydrodynamic solution file to compute approximate flow through any selected cross-section. This utility can now be downloaded from www.tabs.lsu.edu. Key cross-sections were selected for monitoring (Figure C.4-3). A constant discharge was introduced at the diversion input sites. After 31 days, the flow through all of the monitored cross-sections was summed to determine whether water was either gained or lost (Table C.4-1). The results indicate no drift within the first 31 days.

RMA 4, the salinity model, offered the opportunity for a more rigorous test of conservation of mass. All internal and boundary nodes were set to a salinity of 15 ppt and external inputs set to zero. The model was run for 31 days. A single line appears at 15 ppt that for the entire 744 hour run (31 days) masking the output from all 6 target sites. The 15 ppt input value was recovered at all of the target points for each hour to 3 decimal places. The “no marsh” model conserves mass and salt to an acceptable degree for Davis Pond prediction.

Table C.4-1 Conservation of mass (flow) test for RMA2 (hydrodynamics)

Inflow Locations	Flow (cfs)	Outflow Locations	Flow (cfs)
Davis Pond	1,000	Outlet of Little Lake (Grand Bayou)	845
Bayou Des Allemands	260	Outlet of Little Lake (Bayou St. Denis)	750
GIWW	650	Barataria Bay Waterway	280
Total Inflow	1,910	Total Outflow	1,875
		Percent of the Inflow (1910cfs)	98%

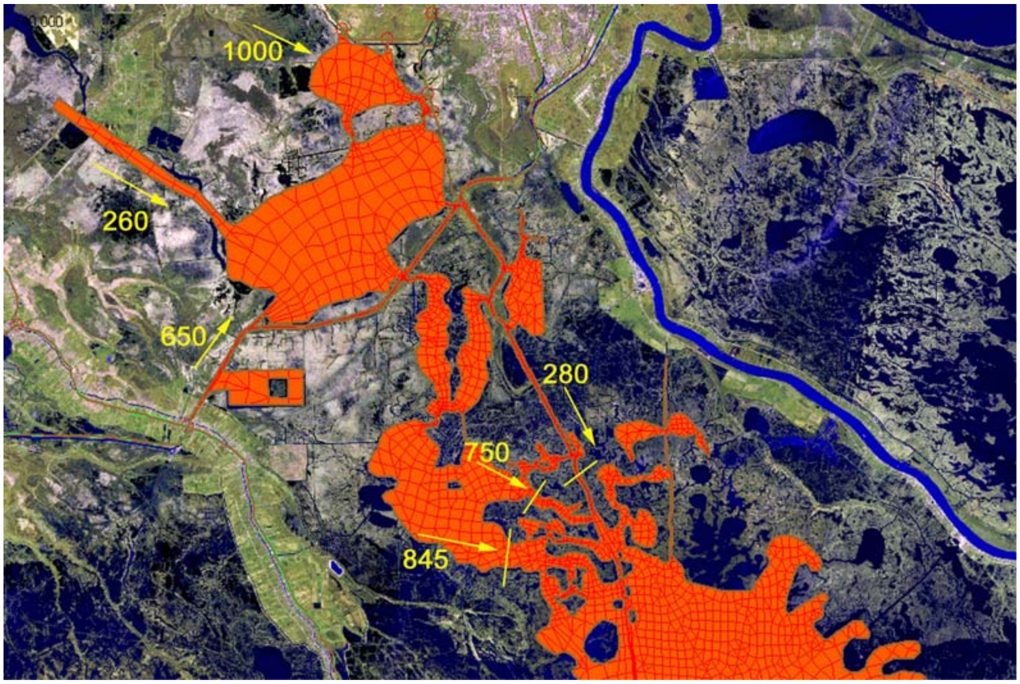

Figure C.4-3 Locations of cross-sections to compute inflow and outflow. Arrows and numbers indicate the flow directions and volume of flow in cfs respectively.

2. *Are salinities at the target locations sensitive to the fidelity with which tidal forcing and salinity is represented at the seaward boundary? Does the model reproduce phase lags at tidal passes?*

The tidal boundary follows the arc that defines the seaward extent of the model domain. For all runs, except when specified otherwise, the tide was input as a simple sinusoid with a 24 hour period and a magnitude of 1.7 ft that oscillated from 0.2 to 1.9 ft about a mean sea level of 1.05 ft NGVD. It was synchronous across the entire boundary arc. As tide data at any real point along the boundary was not available, it was important to be able to reference tide elevations at the boundary to those at the Bayou Rigaud site (Grand Isle) at which the long-term NOAA station is maintained. Also, it was important to understand whether the model geometry reproduced observed phase lags at the passes, or created artificial phase shifts.

Accordingly, the model was run for 31 days and water level input and output was plotted for the boundary and at major passes. It could be seen that the boundary tide was recovered almost unchanged in both amplitude and phase at Pass Abel, Barataria and Caminada Passes. This plot did not show the phase shifts known to exist across the passes, which amount to 1 hour and 45 minutes at most. This inaccuracy is probably not a significant impediment to predicting salinity at the target locations. On the other hand, the way the model is currently set up means that any tide imposed at the seaward boundary is reproduced at Grand Isle. Conversely, an observed Grand Isle tide can be input at the boundary to drive basin dynamics, as is demonstrated later.

Boundary salinity has been represented in the model as a constant, generally 25 ppt. Salinities on the shelf do, in fact, respond to forcing associated with discharge of the Mississippi

River and with the direction of river plume deflection. No real-time salinity data is currently collected on the shelf at the seaward boundary of the model domain, nor is any now proposed. Therefore, no warning of a change in boundary salinity will occur until it shows up at Grand Isle. To understand the error that might be introduced by incorrectly guessing the boundary salinity or its direction of change, a series of six 31-day tests were conducted, using the following conditions:

A. Constant 25 ppt boundary (Figure C.4-4)
B. Constant 20 ppt boundary (Figure C.4-5)
C. Low to High Ramp from 15 to 25 ppt boundary
D. High to Low Ramp from 25 to 15 ppt boundary
E. One Complete Cycle from 15 to 25 ppt and back
F. Two Complete Cycles from 15 to 25 ppt and back

Results of test (a) provide the first opportunity to look at output of the standard run (Figure C.4-4). All plots show salinity at the six target locations for a 31-day period (Figure C.4-2). The three higher salinity lines are along the southern "Ford Line," while the lower three are for the more inland line. All of the lines are more or less wavy, reflecting the influence of the sinusoidal diurnal tide. This tide is more pronounced in the vicinity of the larger passes, but is less noticeable at the westernmost Ford Line site. The westernmost Ford Line site is close to the "no-slip" marsh edge boundary in the "no marsh" model, so this may be something of an artifact.

Effects of various treatments were also tabulated on the basis of monthly mean salinities. If a single month is averaged, the deviation from no action can be considered that which is achieved in half a month or 15.5 days. Along the southern line, mean salinity ranges from 21 to 8 ppt, while the northern target sites range from 2.7 to 0.8 ppt (Table C.4-2). The northern line is more remote from Gulf effects, but the two downstream river diversions at La Reussite and Point a la Hache create a quite noticeable gradient from east (low) to west (high). The effect of varying lateral, lower River diversion discharges could be explored further in future efforts.

The other result of this exercise was the discovery that salinities at the target points are essentially unaffected by changes in boundary salinities over a period as short as 31 days. This conclusion suggests that it may not be necessary to have precise shelf salinities in order to make reasonable salinity predictions within the basin for periods of a month or less.

Table C.4-2 Effect of Varying Boundary Salinity on Target Salinity (31 day average, all values in ppt)

Test	N4968	N4479	N2236	N3556	N5030	N5730
20ppt	21.1	14.1	8.3	2.7	1.0	0.8
25ppt	21.2	14.2	8.3	2.7	1.0	0.8
ramp 15-25	21.0	14.0	8.3	2.7	1.0	0.8
ramp 25-15	21.2	14.2	8.3	2.7	1.0	0.8
1 cycle 15-25	21.1	14.1	8.3	2.7	1.0	0.8
2 cycle 15-25	21.0	14.1	8.3	2.7	1.0	0.8

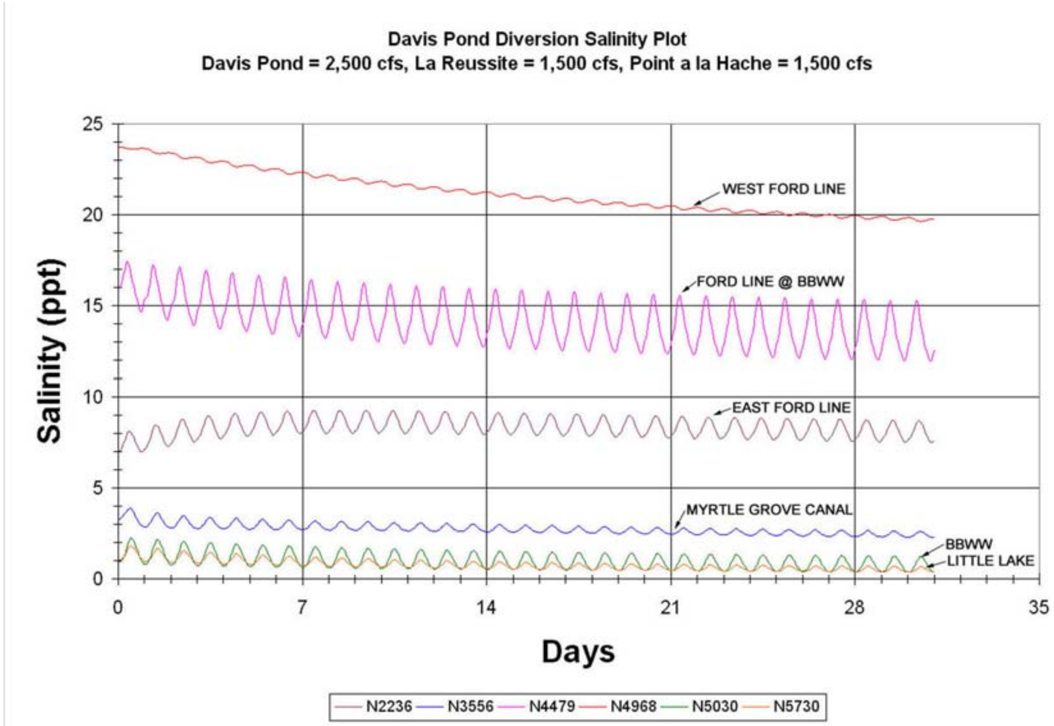

Figure C.4-4 Salinity plot with a 25 ppt constant Gulf boundary.

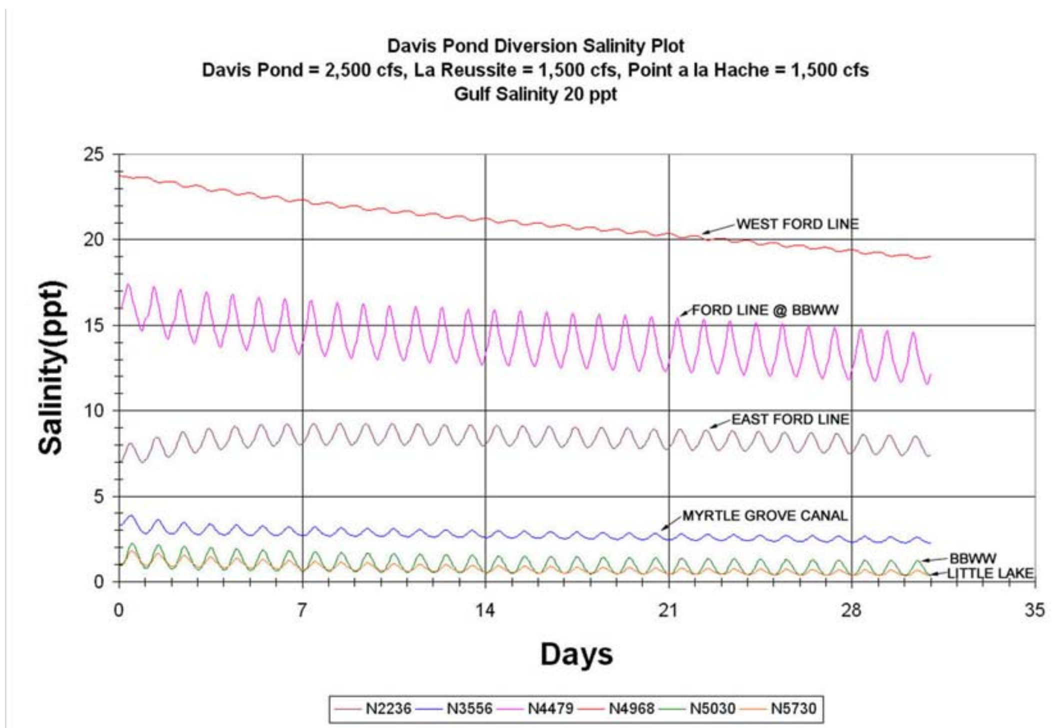

Figure C.4-5 Salinity plot with a 20 ppt constant Gulf boundary.

3. How sensitive are salinities at the target locations to wind forcing?

Two series of tests were run for the standard set-up. The first set of results are for 31-day runs with winds of constant velocity and direction, while the second set of results are for 62-day simulations that include a 180^o wind shift. The following list summarizes the two sets of simulations performed:

A. 31 Day Simulations
   i. No Wind (Figure C.4-6)
   ii. Standard – constant 5.75 mph from south
   iii. Twice Wind – constant 11.50 mph from south
   iv. Thrice Wind – constant 17.25 mph from south (Figure C.4-7)

B. 62 Day Simulations
   i. 7 days at 17.25 mph from the south, then 7days from north, then 48 days @5.75 mph from south (Figure C.4-8)
   ii. 7 days at 17.25 mph from the north, then 7 days from south, then 48 days @5.75 mph from north.

Winds modify the water level gradient and volume of water in the basin. Southerly winds drive high salinity waters from the shelf adjacent to the passes into the lower bays, while northerly winds expel the highest salinity water from the basin. As wind speed increases, tidal influences on salinity (and water level) are reduced. Increasing southerly wind speeds from 5.75 to 17.25 mph resulted in an increase in mean salinity on the westernmost of the Ford Line target sites by about 4 ppt but had no influence on the inner line sites or on the eastern Ford Line site influenced by the lower River diversions (Table C.4-3).

The pulsed wind simulations are closer to actual conditions associated with cold front passages. Moderately strong northerly winds can drop salinities at the western Ford Line sites by as much as 10 ppt, particularly if preceded by strong southerlies, but the effect is not uniform from east to west along the line (Figure C.4-8). North winds appear to reduce the influence of the lower River diversions on the eastern Ford Line site, driving salinity up. As might be expected, northerly winds have little effect on salinities at target sites along the interior line, as these are quite fresh to begin with. Strong, steady southerlies drive salinities up at all target sites, though generally less than 5 ppt.

Table C.4-3 Effect of Varying Wind Speed on Target Salinity (South Wind, 31 day average, all values in ppt)

Test	N4968	N4479	N2236	N3556	N5030	N5730
0 mph	20.7	13.8	8.3	2.7	1.0	0.8
5.75 mph	21.2	14.2	8.3	2.7	1.0	0.8
11.50 mph	22.9	15.6	8.5	2.8	1.0	0.8
17.25 mph	24.3	17.7	8.6	2.9	1.0	0.8

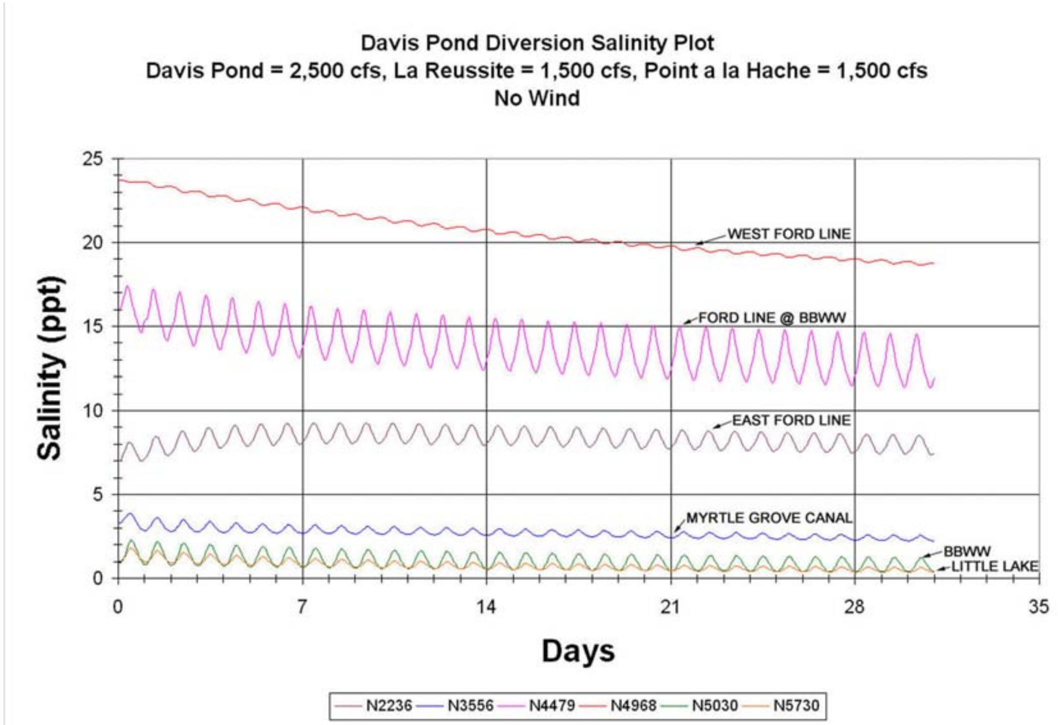

Figure C.4-6 Salinity plot for no wind condition.

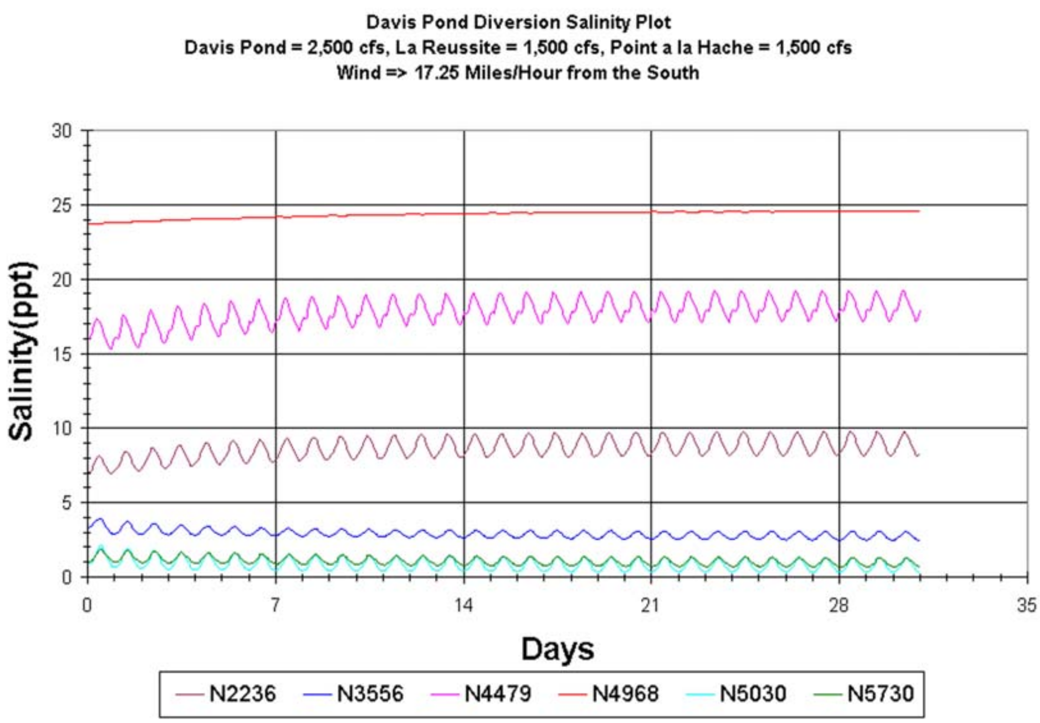

Figure C.4-7 Salinity plot for 17.25 mph wind condition

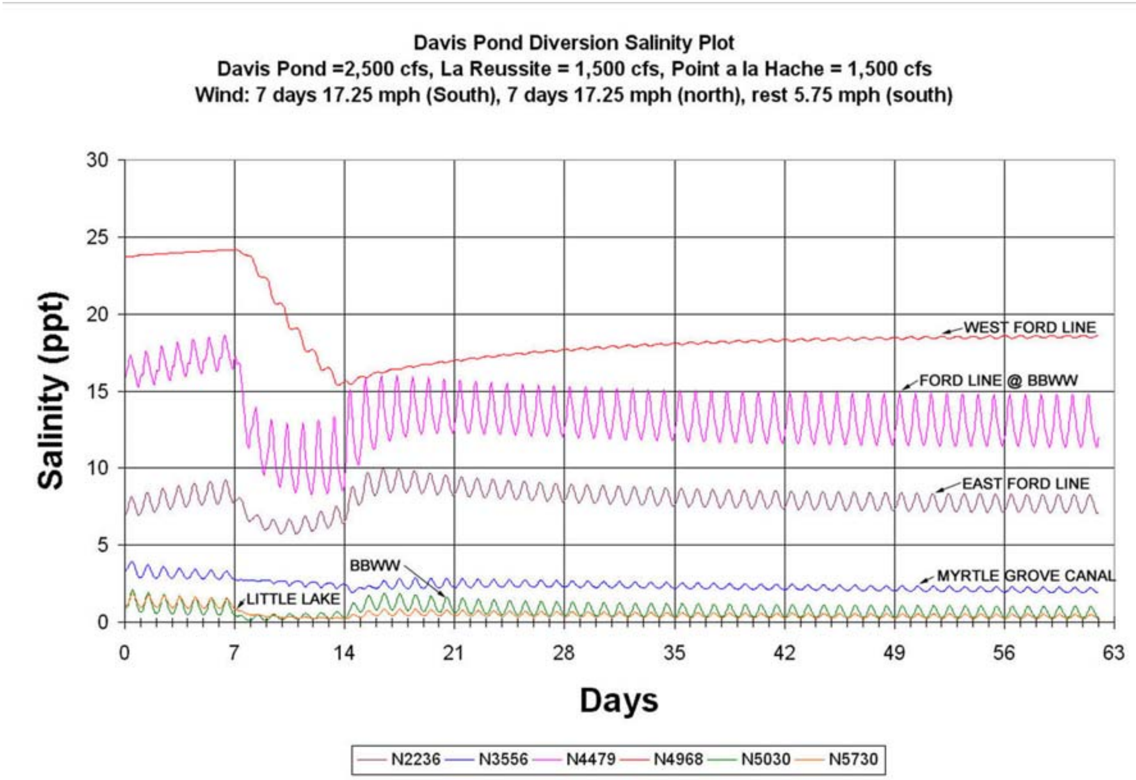

Figure C.4-8 Salinity plot for variable wind condition.

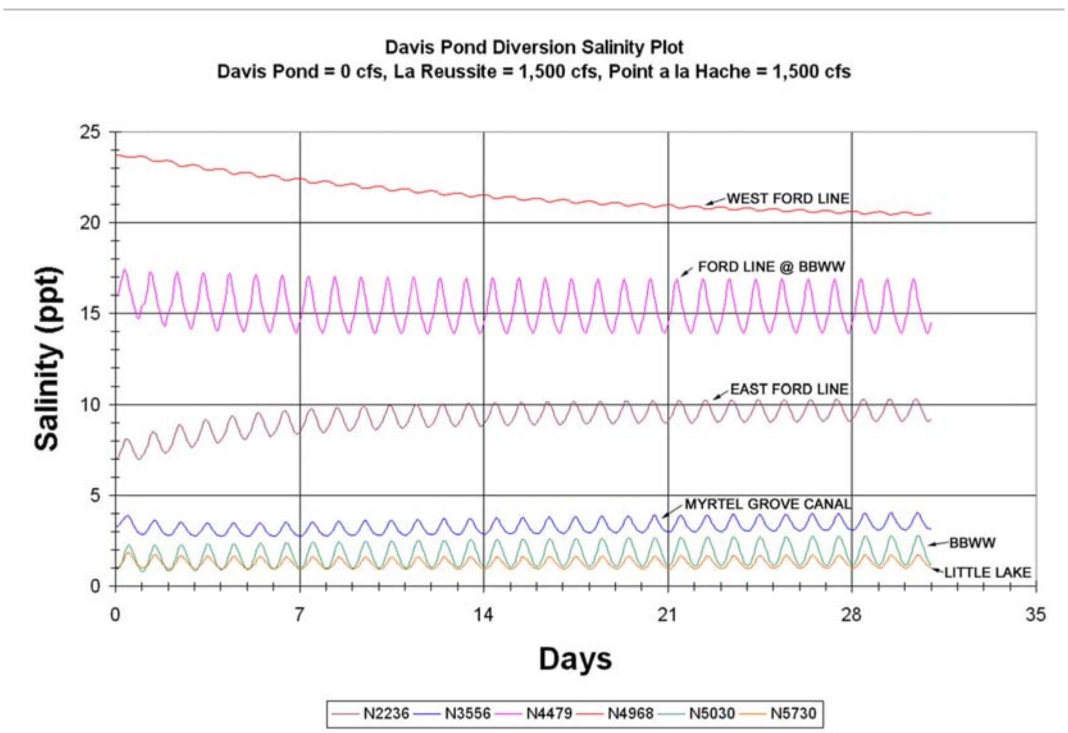

Figure C.4-9 Salinity plot for 0 cfs diversion at Davis Pond.

4. How sensitive are salinities at the target locations to changes in Davis Pond discharge?

Two series of tests were run for the standard set-up. The first results are for 31-day runs with constant Davis Pond discharges, while the second are for 62-day simulations that include pulses. The various discharges used for the simulations run are listed below:

A. 31 Day Simulations
   i. 0 and 1,000 cfs Davis Pond (Figure C.4-9)
   ii. 2,000 cfs Davis Pond
   iii. 2,500 cfs Davis Pond (Figure C.4-10)
   iv. 5,000 cfs Davis Pond (Figure C.4-11)
   v. 7,500 cfs Davis Pond (Figure C.4-12)
   vi. 10,600 cfs Davis Pond (Figure C.4-13)

B. 62 Day Simulations
   i. 2,500 cfs Davis Pond for 21 days, then off (Figure C.4-14)
   ii. 5,000 cfs Davis Pond for 21 days, then off (Figure C.4-15)
   iii. 10,600 cfs Davis Pond for 21 days, then off

Davis Pond discharges of various magnitudes were predicted by the model to reduce salinity linearly at any site to about 3 ppt, after which the influence was better described as an exponential or asymptotic decline. While the water level gradient associated with any particular discharge was set up quickly, the model predicted that salinity change at the target sites would be quite gradual (Table 4.4). The reduction predicted after 31 days at the target sites, after the tidal oscillation was removed, ranged from about 0.2 to 0.8 ppt for each 1,000 cfs of Davis Pond discharge (Table 4.5). These reduction rates were obtained by doubling the deviation of the 31-day mean salinity from the initial condition. The model predicted that this change, although slow, did not stop. There was no saturation, so that even a relatively minor discharge like 2,000 cfs, if continuous, was predicted to eventually freshen the entire basin.

Results of three 21-day pulsed discharge tests (Figures C.4-14, 4-15) provided important information about predicted salinity response. All plots showed an immediate, nearly linear suppression of salinity that ends within one or two days of the shutdown. The relaxation to pre-diversion conditions varied from site to site but was generally elastic, that is, salinities returned to near antecedent condition within another 3 to 4 weeks.

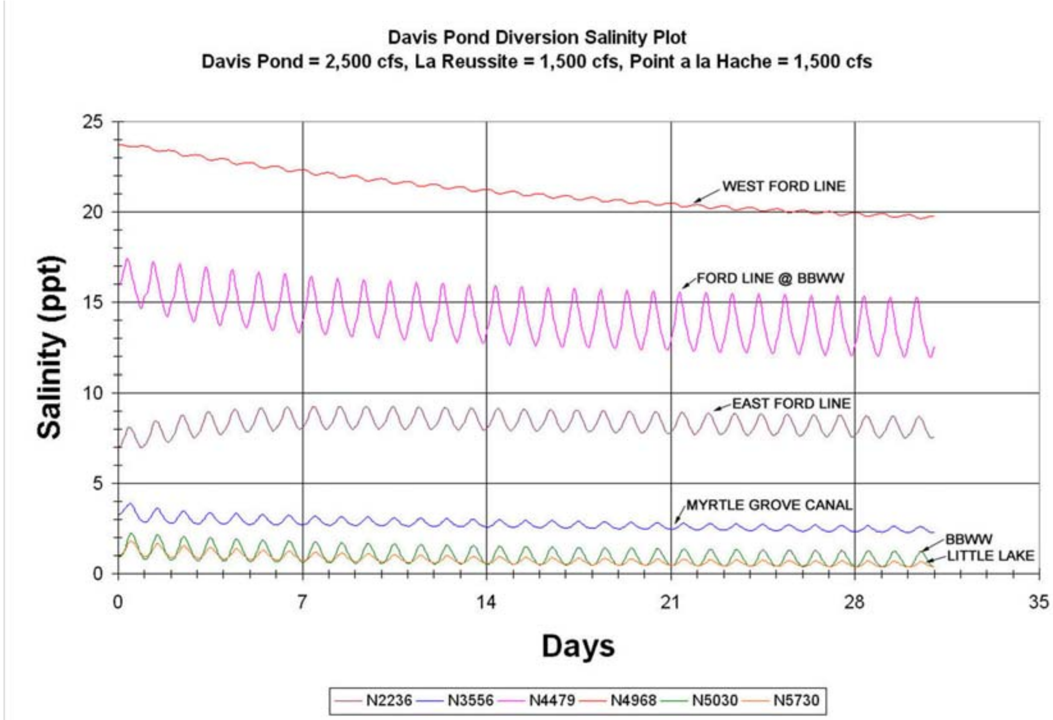

Figure C.4-10 Salinity plot for 2500 cfs diversion at Davis Pond

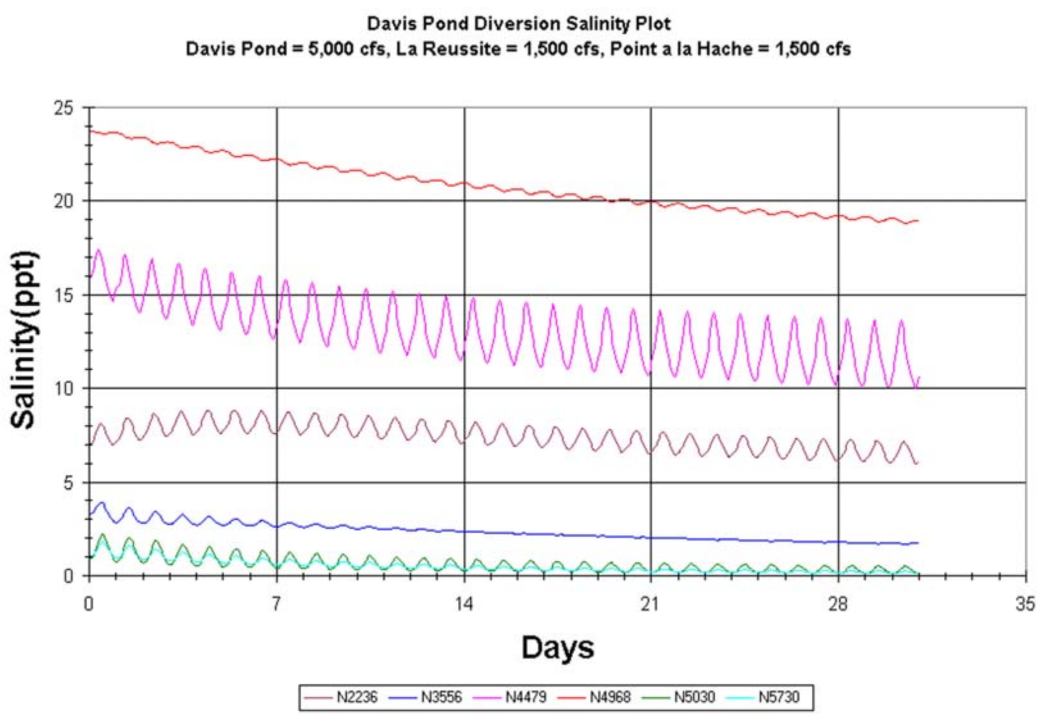

Figure C.4-11 Salinity plot for 5000 cfs diversion at Davis Pond.

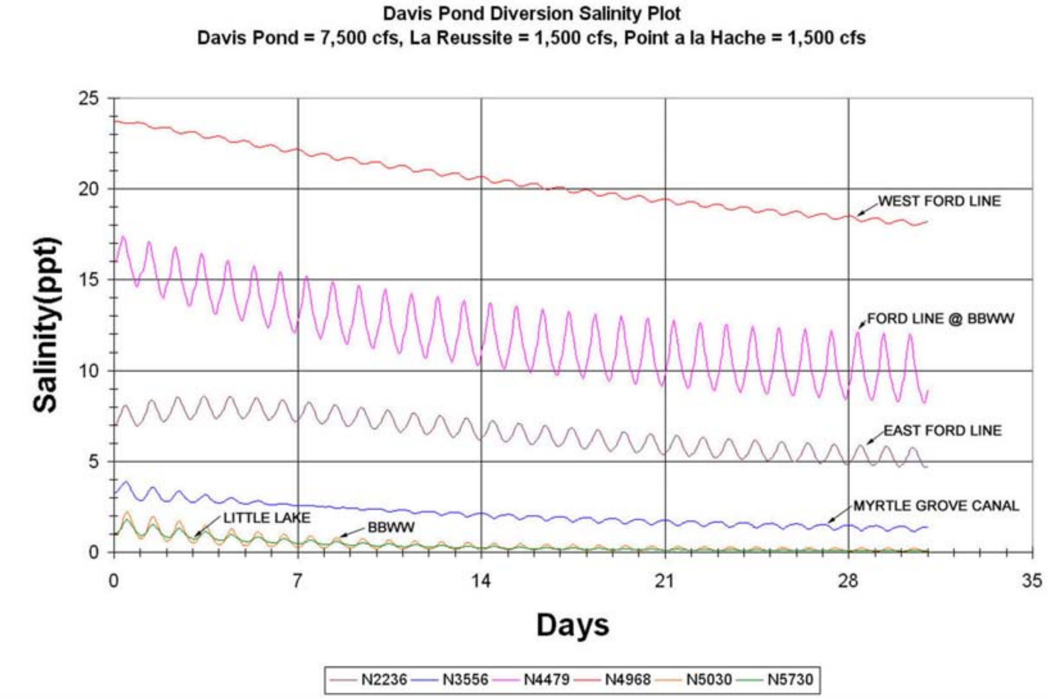

Figure C.4-12 Salinity plot for 7500 cfs diversion at Davis Pond

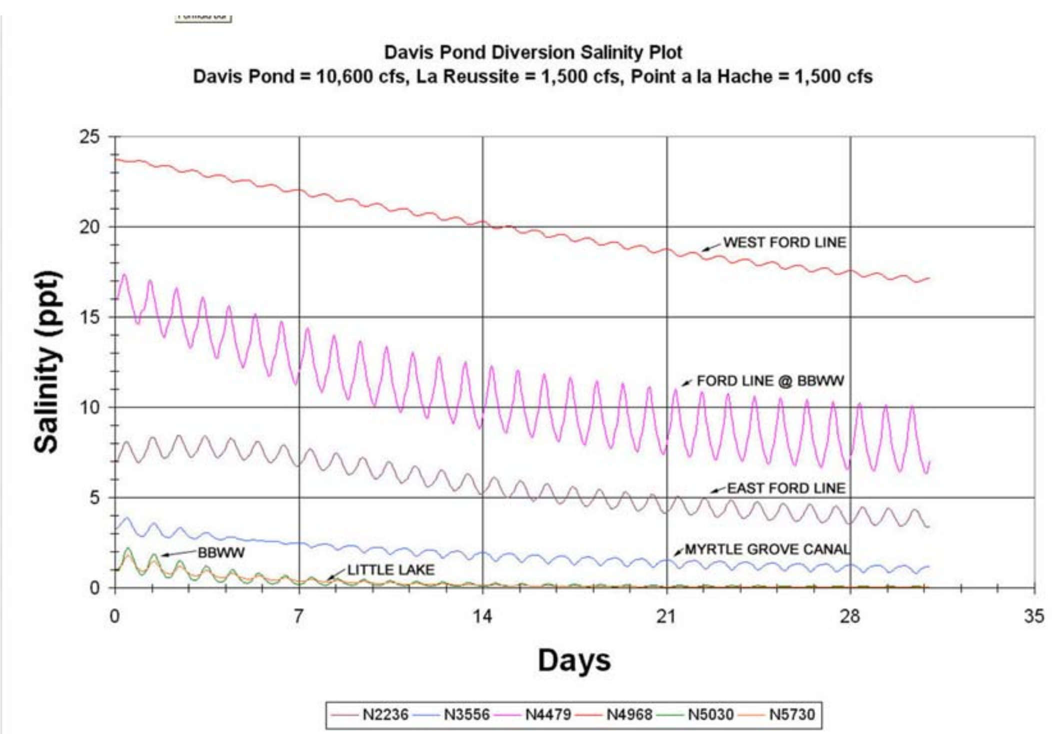

Figure C.4-13 Salinity Plot for 10600 cfs diversion at Davis Pond

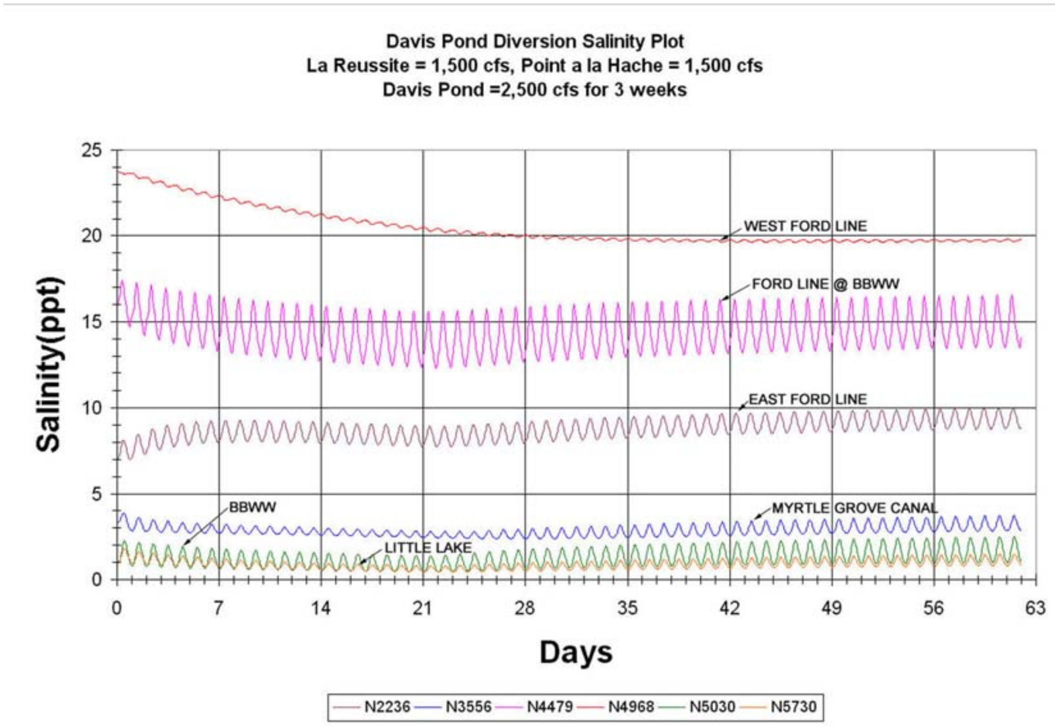

Figure C.4-14 Salinity plot for 2500 cfs diversion at Davis Pond for 21 days, then off.

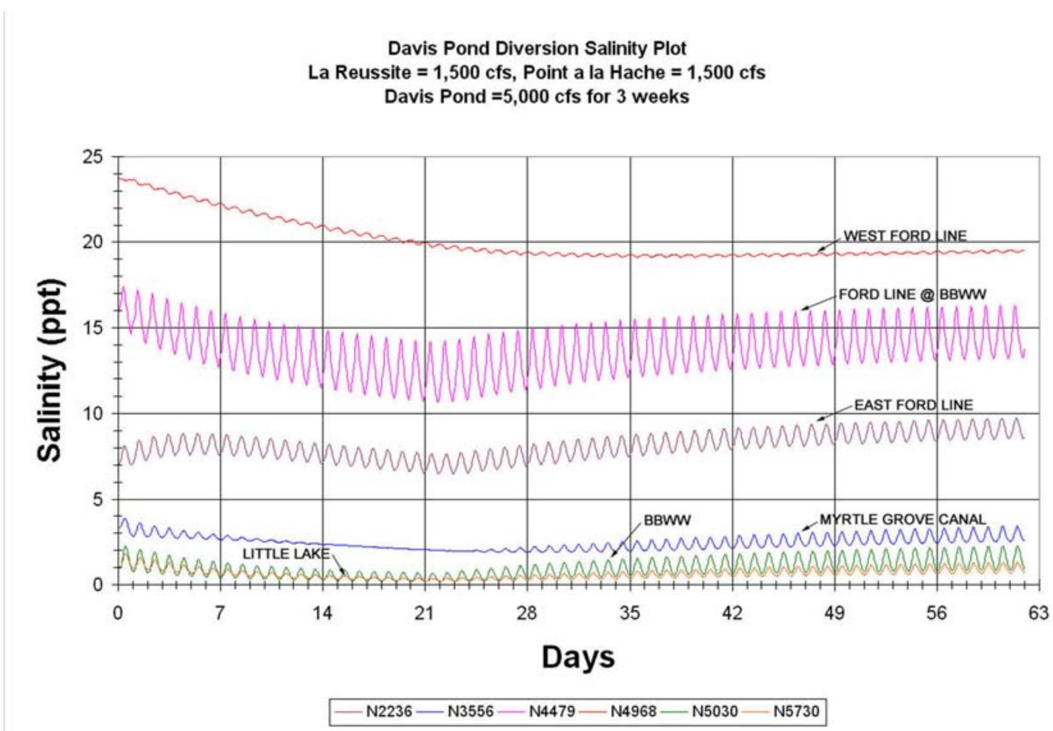

Figure C.4-15 Salinity plot for 5000 cfs diversion at Davis Pond for 21 days, then off.

Table C.4-4 Effect of Davis Pond Discharge on Target Salinity*

Test CFS	N4968	N4479	N2236	N3556	N5030	N5730
0	21.6	15.3	9.2	3.0	1.4	1.0
1000	21.4	14.8	8.9	3.0	1.4	1.0
2000	21.3	14.4	8.5	2.8	1.1	0.8
2500	21.2	14.2	8.3	2.7	1.0	0.8
5000	20.9	13.1	7.4	2.3	0.6	0.5
7500	20.5	12.0	6.6	2.1	0.4	0.4
10600	20.0	10.7	5.7	1.9	0.3	0.3
Values reported can also be considered a mid-month (15.5 day) result. *(South Wind, 31 day average, all values in ppt)*						

Table C.4-5 Salinity Reduction Associated with each 1,000 cfs of Davis Pond Discharge After 31 Days

Test	N4968	N4479	N2236	N3556	N5030	N5730
1000	-0.2	-0.8	-0.6	-0.2	-0.2	-0.2
(all values in ppt						

4.3 Dynamic Winds and Tides

4.3.1 Introduction

This section discusses the continued testing of the “no marsh” TABS-MD Barataria model created by Mr. David Elmore of the U.S. Army Corps of Engineers (USACE). The objective for this analysis was to independently validate the model for salinity in the target.

4.3.2 Methods

Grand Isle water levels and winds from April and May, 1997, were acquired and set up to drive the model (Figure C.4-16, 4-17, 4-18). Three 62-day runs were made to provide a more realistic picture of what to expect when the diversion is in operation, at least during the winter and spring when cold air outbreaks dominate weather. A 500 cfs diversion run was made that provided salinity output time-series at St. Mary’s Point and Grand Terre where the Louisiana Department of Wildlife and Fisheries (LDWF) has collected hourly salinity data for some time (Figure C.4-19). A 500 cfs diversion at Davis Pond was used to simulate a nearly no discharge condition as it was found that the model became unstable if very low or zero discharge was specified. Next, the functions described by the SRF nomographs provided by the USACE were programmed for a 5 ppt and a 15 ppt station to see how well the model output tracked results predicted by the graphs.

4.4 Results and Discussion

4.4.1 Barataria Bay Conditions in April and May, 1997

The wind data showed that two cold fronts and a number of lesser events affected Barataria Bay in the first month (Figures C.4-17, and C.4-18). Conditions were far less energetic in the second month (May). The tide data showed the impact of the winds and rotation associated with the fronts on coastal water level (Figure C.4-16). The influence of the astronomical tide was still present but was at times almost masked by the higher amplitude lower frequency oscillations. These low frequency water-level excursions resulted from wind effects that operated over the shelf far beyond the model domain.

Salinity for this period was available in Barataria Bay from Grand Terre on the south and St. Mary's Point on the north (Figure C.4-17). These stations are located just south of the 15 ppt and 5 ppt lines, respectively. Stations 317 and 315 at St. Mary's Point were compared to model output for N3556 and N4479, respectively (Figure C.4-20).

Mean salinities for April, 1997, at the 5 ppt station (St. Mary's Point No. 317) and 15 ppt station (Grand Terre No. 317) were 8.2 (4.2) and 16.3 (2.5) ppt, respectively, indicating an average gradient along the axis of the bay of 8 ppt. In May, the north-south gradient was steeper, 11.4 ppt, as observed salinities at the 5 and 15 ppt stations averaged 4.6 (1.8) and 16.0 (2.3) ppt, respectively. Salinity responds rapidly to the sequential filling and emptying of the bay associated with oscillations in shelf water level, rising as high salinity water is forced in from the shelf, and falling as Gulf level drops and the basin drains.

Salinity at St. Mary's Point is more sensitive to the extent of wind-induced mixing than at Grand Terre. Values at St. Mary's Point ranged from near zero to more than 18 ppt in April and from 2 to 8 ppt in May. At Grand Terre, salinity ranged from 11 to 22 ppt for both months. The difference in variability was clear. One standard deviation was between 40 and 50 percent of the mean salinity at St. Mary's Point, but was only 15 percent of the mean at Grand Terre.

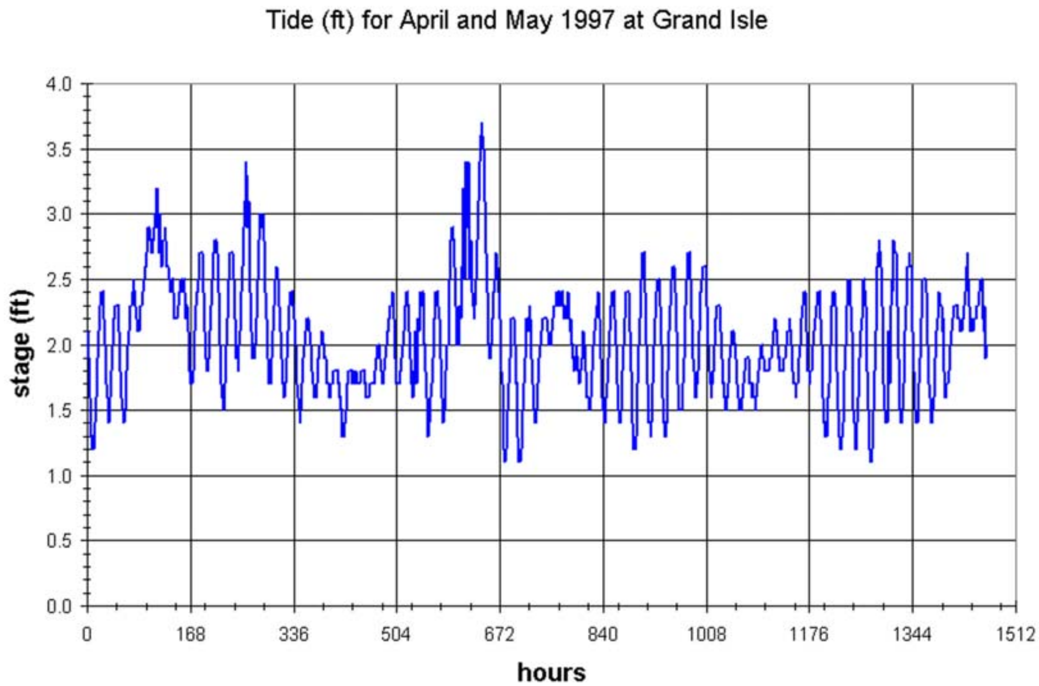

Figure C.4-16 Grand Isle Tide for April and May 1997

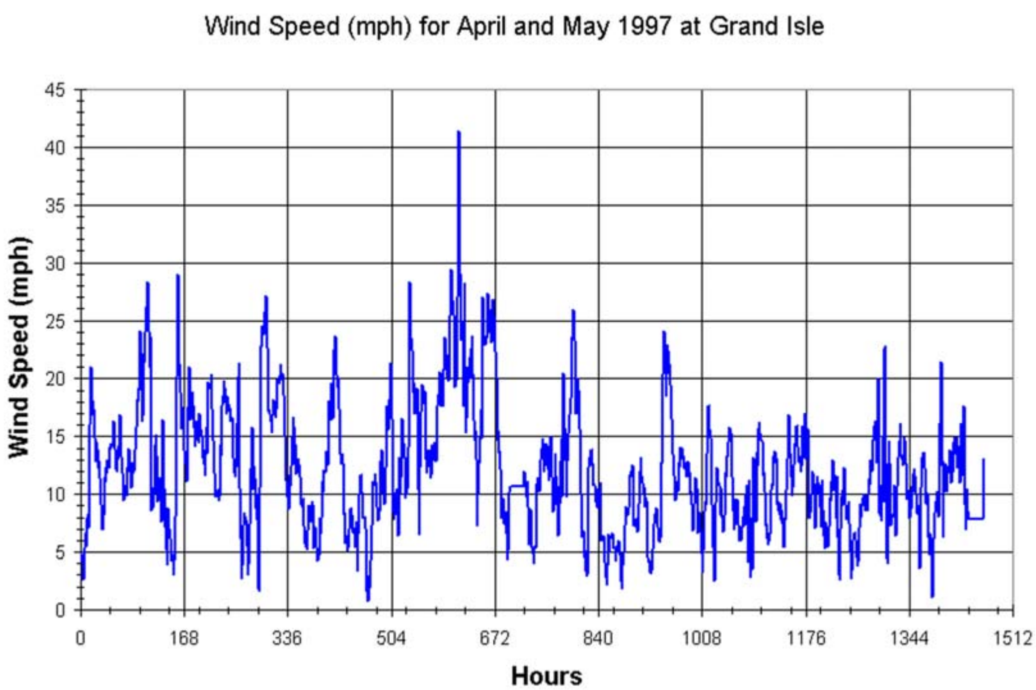

Figure C.4-17 Grand Isle Wind Speed for April and May 1997

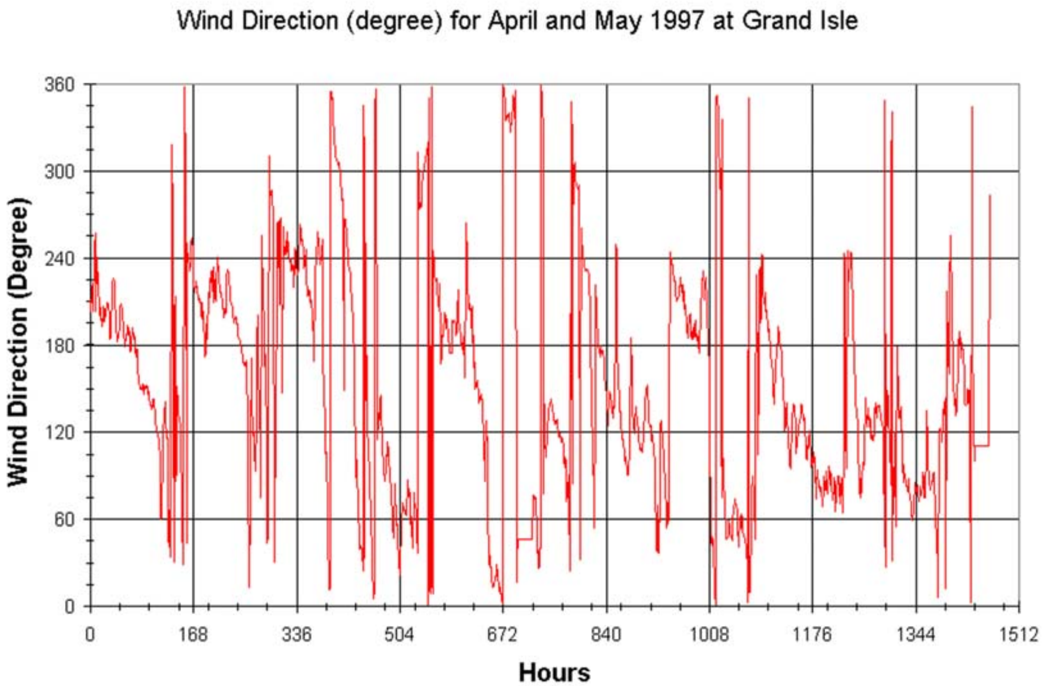

Figure C.4-18 Grand Isle Wind Direction for April and May 1997

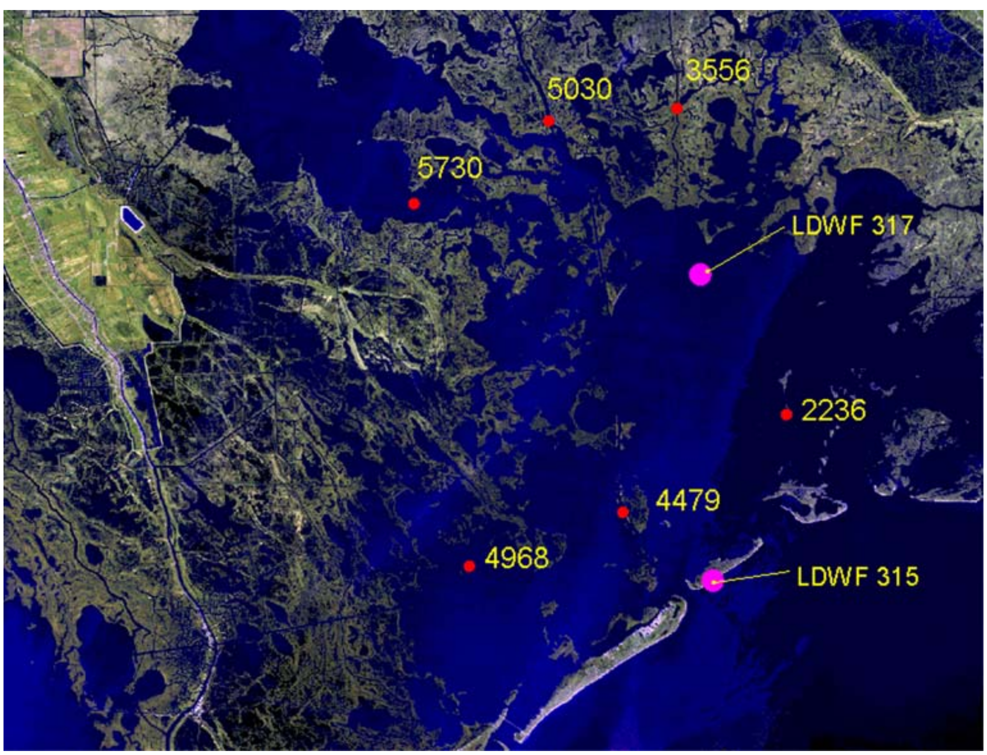

Figure C.4-19 Location of Davis Pond SRC stations and LDWF Salinity stations 315 (Grand Terre) and 317 (St. Mary's Point).

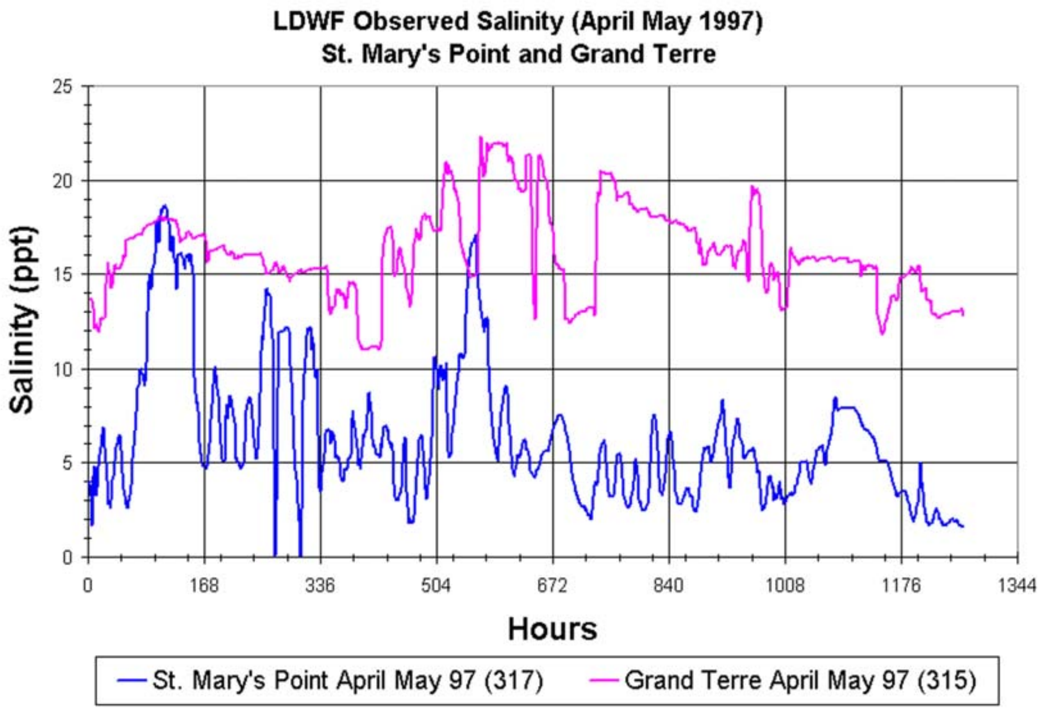

Figure C.4-20 Observed salinity at St. Mary's Point (317) and at Grand Terre (315) for April and May 1997

4.4.2 Verification

Two 62-day runs of the model were made in which salinity output was requested at the locations of LDWF stations 317 and 315, the two points within the area of interest where continuous salinity time-series were available; the conditions for these runs are listed below. Model output and observed salinities were plotted for each location on common axes.

A. St. Mary's Point Station 317 was compared to model prediction for 500, 2,500 and 10,600 cfs Davis Pond diversion with April and May, 1997, Grand Isle tide and wind (Figure C.4-21)

B. Grand Terre Station 315 was compared to model prediction for 500, 2,500 and 10,600 cfs Davis Pond diversion with April and May, 1997, Grand Isle tide and wind (Figure C.4-22)

The predicted influence of Davis Pond discharge on salinity at the two stations is one of gradual divergence from the low "no discharge" (500 cfs) condition, as was predicted from the static runs. Overall comparisons for April 1997 with low discharge (500 cfs) model predictions show that when the standard set-up was followed (see Phase I report), the model underpredicted salinity by 1.2 ppt at St. Mary's Point and by 1.7 ppt at Grand Terre resulting in error of 15 and 10 percent, respectively (Table C.4-6).

Table C.4-6 Comparison of Predicted and Observed Salinities for April and May 1997

Station	LDWF No.	Observed	Predicted	Obs. - Pred.	% Error
St. Mary's Point	317	8.2	7.0	1.2	15
Grand Terre	315	16.3	14.6	1.7	10

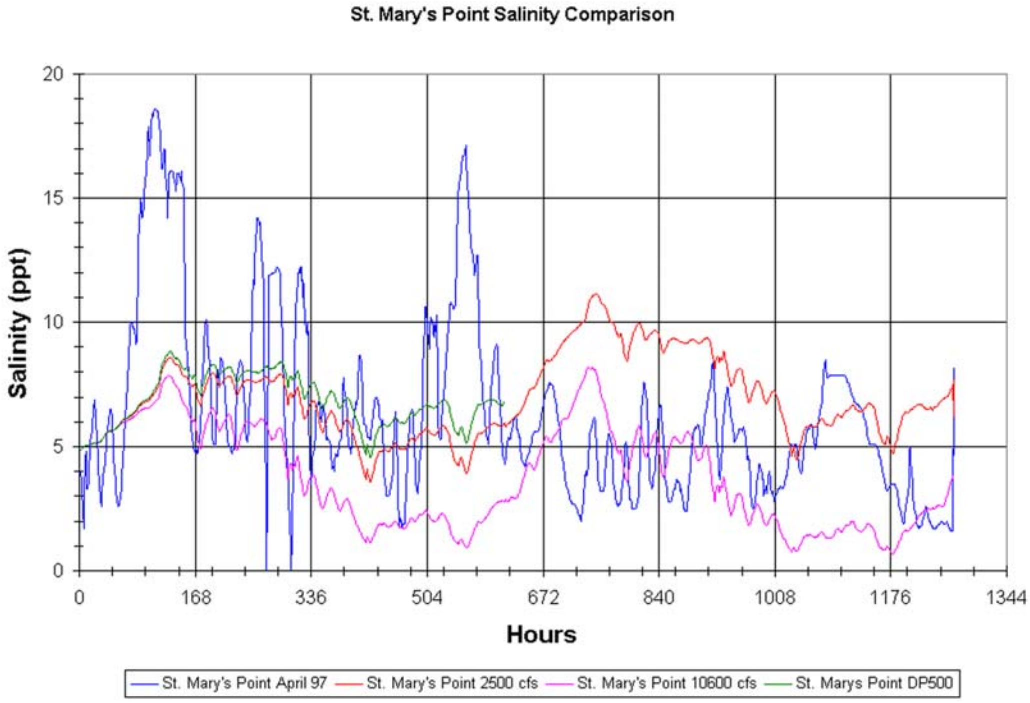

Figure C.4-21 St. Mary's Point Station 317 compared to model predictions for 500, 2,500 and 10,600 cfs Davis Pond diversion. Data from April and May 1997.

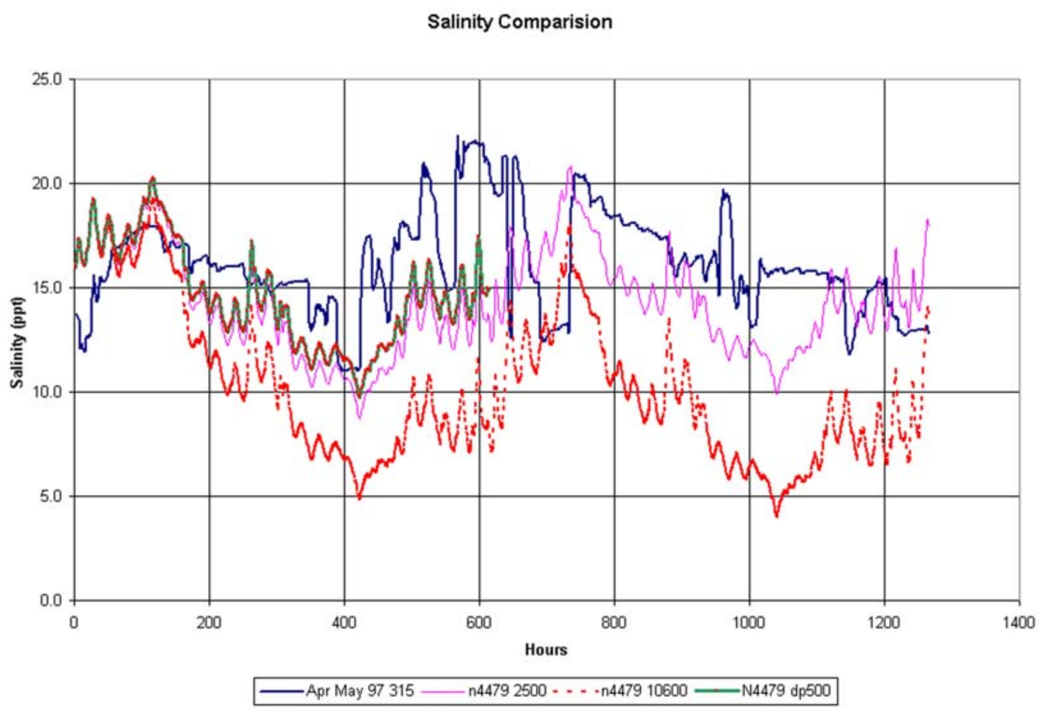

Figure C.4-22 Grand Terre Station 315 compared to model predictions for 500, 2,500 and 10,600 cfs Davis Pond diversion. Data from April and May 1997.

At St. Mary's Point in northern Barataria Bay, the model predicted mean conditions well in April, although it did not capture two 10 ppt spikes that persisted for 2 to 3 days each (Figure C.4-21). The model predicted that salinity in May should be somewhat higher than in April, but observed salinity actually decreased, so that predictions for all of May were about 5 ppt higher than observed. The model predicted somewhat less variation than was observed in the vicinity of the 5 ppt line, but suggested that this variation will be minimally affected by discharge from the structure (Table C.4-8). In other words, the model predicted that 66 percent of all observations in the vicinity of the 5 ppt line would fall within +/- 2 ppt of the mean predicted or sought. This is similar to what the field data shows.

Table C.4-7 Effect of Varying Davis Pond Discharge on Target Salinity with Jan & Feb 1997 Winds and Tides

Dynamic Test	N4968	N4479	N2236	N3556	N5030	N5730
500 cfs – Month 1	18.5	14.7	11.0	4.6	3.5	2.9
2,500 cfs - Month 1	17.7	14.4	11.3	4.6	3.4	2.7
2,500 cfs - Month 2	16.3	15.0	12.4	5.6	4.2	3.4
10,600 cfs - Month 1	15.8	11.3	9.0	3.3	1.6	1.2
10,600 cfs - Month 2	11.7	9.6	8.8	2.4	0.8	0.4
Predicted from Salinity Reduction Relationship						
Static Test	N4968	N4479	N2236	N3556	N5030	N5730
0 cfs	21.6	15.3	9.2	3.0	1.4	1.0
2,500 cfs - Month 1	21.4	14.8	8.8	2.9	1.3	0.9
2,500 cfs - Month 2	20.9	13.8	8.0	2.6	1.0	0.7
10,600 cfs - Month 1	20.5	13.2	7.6	2.5	0.9	0.6
10,600 cfs - Month 2	18.4	8.9	4.4	1.4	0.0	0.0
Deviation = Static - Dynamic						
Comparison	N4968	N4479	N2236	N3556	N5030	N5730
0 cfs	2.9	0.6	-1.8	-1.6	-2.1	-1.9
2,500 cfs - Month 1	3.6	0.4	-2.5	-1.7	-2.2	-1.8
2,500 cfs - Month 2	4.5	-1.2	-4.4	-3.0	-3.2	-2.7
10,600 cfs - Month 1	4.8	1.8	-1.5	-0.8	-0.7	-0.6
10,600 cfs - Month 2	6.7	-0.7	-4.4	-1.0	-0.8	-0.4
Mean Deviation	4.5	0.2	-2.9	-1.6	-1.8	-1.5
31 day averages, all values in ppt) Comparison of Dynamic and Static Results						

Table C.4-8 Comparison of Monthly Salinities Observed and Predicted Using the Dynamic and Static Model Runs

Observed	Month	St. Mary's Point	N5030	Grand Terre	N4479
0 cfs	Apr-97	8.2 (4.2)		16.3 (2.5)	
	May-97	4.6 (1.8)		16.0 (2.3)	
Model					
500 cfs	Apr-97 May-97	6.9 (1.0)	3.5	14.7 (2.4)	14.7 (2.4)
2500 cfs	Apr-97	6.2 (1.4)	3.4 (1.7)	14.0 (2.7)	14.4 (2.7)
	May-97	7.7 (1.8)	4.2 (2.1)	14.7 (2.2)	15.0 (2.2)
10600 cfs	Apr-97	4.1 (2.0)	1.6 (1.7)	11.0 (4.0)	11.3 (4.0)
	May-97	3.5 (2.1)	0.8 (1.1)	9.4 (3.0)	9.6 (3.0)
SRF					
2500 cfs	Apr-97		7.4		15.5
	May-97		3.5		14.1
10600 cfs	Apr-97		2.4		12.1
	May-97		0.4		7.4
All values in ppt, One Standard Deviation In Parentheses					

At the Grand Terre location, model prediction was close to observed for the first 450 hours (Figure C.4-22). Observed salinities then increased more rapidly than predicted by the model, although the model reached the same maximum about 200 hours later. The model predicted the subsequent decline to 1150 hours. At this point, the model predicts that salinity should increase, while observed values actually declined. It is likely that a rapid increase in river discharge that took place at this time was freshening the shelf and changing boundary salinity conditions. Under fully dynamic conditions, the model responds more rapidly to changes in boundary salinity than was reported for static runs.

The model predicted about the same variation as was actually observed in the vicinity of the 15 ppt line, but suggested that this variation might increase as a function of discharge from the structure (Table 4.8). In other words, the model predicted that 66 percent of all observations in the vicinity of the 15 ppt line would fall within +/- 3 ppt of the mean predicted or sought. This is similar to what the field data shows. After a prolonged period of relatively high discharge, lower bay salinities can be expected to start showing the higher variability that is observed today in the upper bay.

April 1997 hourly salinities predicted by the model for a 500 cfs Davis Pond discharge were compared with observed Grand Terre data after both were smoothed by a 3-day running average (Figure C.4-23). If the model could fully explain all phenomena, then this plot would follow a single line or curve, and the relationship between predicted and observed values would be the same no matter when comparisons were made during the month. In fact, at least two or three trends were apparent during the single month compared. It was clear that factors other than those captured by the model, for example, changes in boundary salinity, are affecting salinity at Grand Terre.

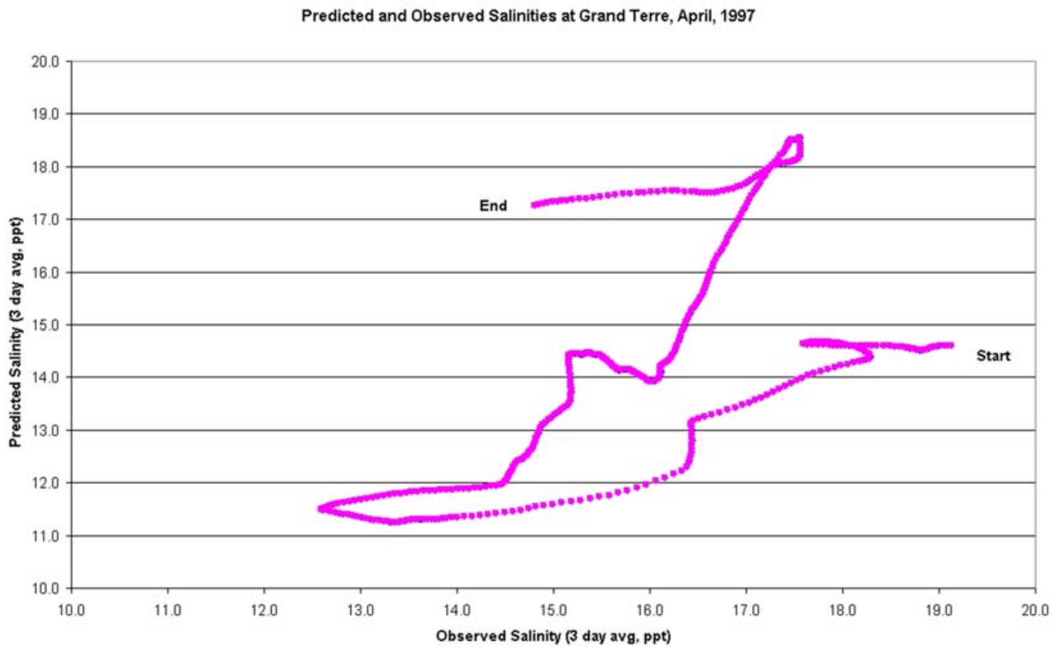

Figure C.4-23 Comparison of Predicted and Observed Salinities at Grand Terre for "no" Davis Pond discharge (actually 500 cfs) for April, 1997.

4.4.3 Dynamic vs. Static Simulation

Two 62-day runs of the "no marsh" model were made that produced output at the six target locations. These runs are listed below:

A. Constant 2,500 cfs diversion with April and May, 1997, Grand Isle tide and wind (Figure C.4-24)

B. Constant 10,600 cfs diversion with April and May, 1997, Grand Isle tide and wind (Figure C.4-25)

The results of these runs were quite different from the static simulations for the same discharge, but with little wind, no shelf interactions and a monotonic tide. While most of the salinity plots for the target locations were sub-parallel and separate in the earlier tests, they blended and crossed each other in the latest runs. It was apparent that far more mixing is taking place in Barataria Bay as a result of secondary circulation patterns that set up over time in response to the wind forcing.

Mean salinity at each target site was calculated for each of the two months. These dynamic results were compared to the static results (Table C.4-7).

Three important differences were noted between the dynamic and static results. First, the cross-basin gradients in the lower bay were greatly reduced from the static conditions, despite the influence of the lower river diversions at West Pt. A la Hache and La Reussite. On the Ford Line, the difference in second month (May) salinity between east (N2236) and west (N4968) was reduced from a static 13 ppt to a dynamic 4 ppt for a 2,500 cfs Davis Pond discharge. For the 10,600 cfs test, the same range decreased from a static 14 ppt to 3 ppt in the dynamic simulation. While salinities in the west were decreased and those on the east raised in the dynamic test, predicted mean salinities at the central station (N4479) were similar in both the static and dynamic runs. Second, the dynamic simulation did not change the cross-basin gradient along the interior line, but salinities were about twice those predicted from the static relationship for both discharges and months (Table C.4-7). Finally, salinities at all stations except the westernmost Ford Line site (N4968) generally increased over the two months simulated for the 2,500 Davis Pond discharge. Decreases were observed between months 1 and 2 for the 10,600 cfs discharge, however.

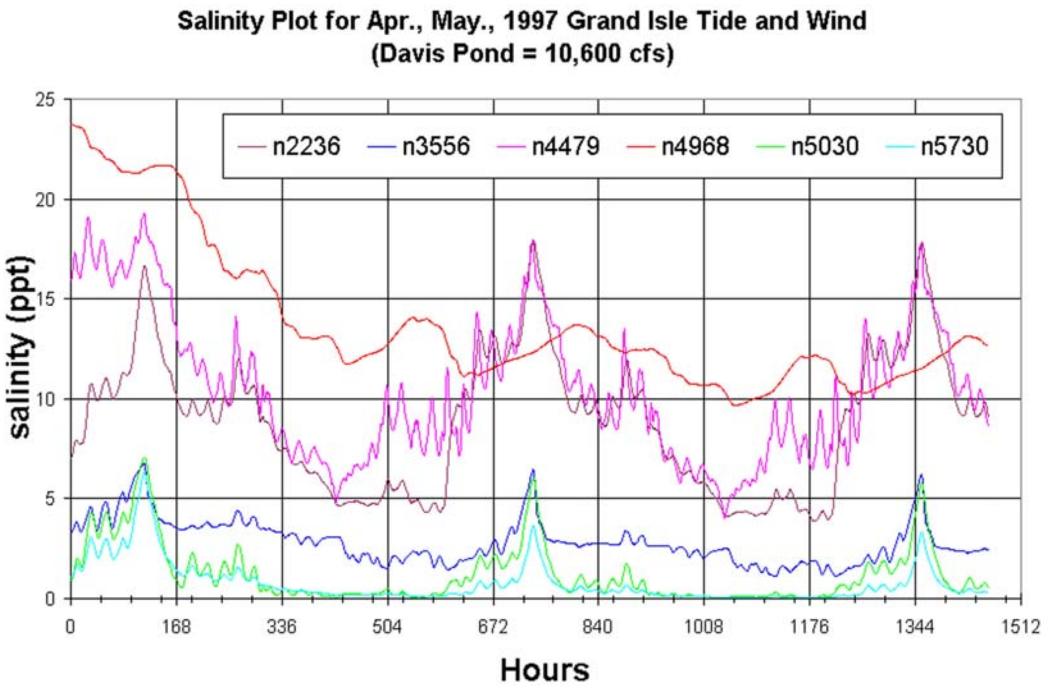

Figure C.4-24 Salinity Plot 62 days with Grand Isle tide and wind. Davis Pond Diversion 2,500 cfs

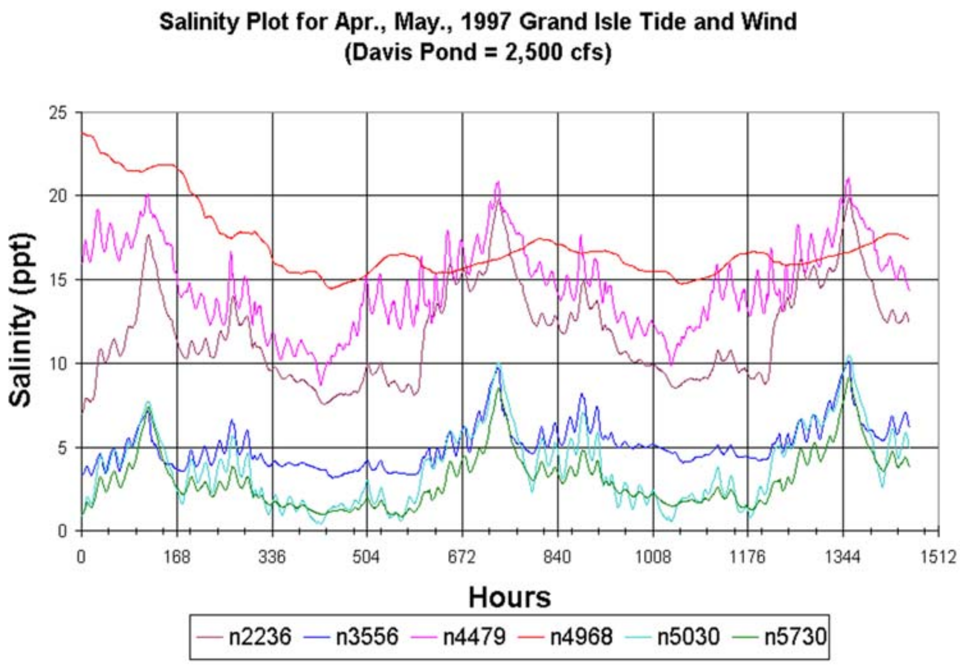

Figure C.4-25 Salinity plot 62 days with Grand Isle tide and wind. Davis Pond Diversion 10,600 cfs

4.5 More Sensitivity Analyses

4.5.1 Introduction

Louisiana State University (LSU) researchers were asked to establish the utility of a TABS model developed by the U. S. Army Corps of Engineers (USACE) to predict salinities at target locations in the Barataria Basin downstream of the Davis Pond diversion structure. This section describes the continued testing of the "no marsh" and "with marsh" TABS-MD Barataria models created by Mr. David Elmore of the U.S. Army Corps of Engineers (USACE). Further sensitivity analyses of boundary effects for fully dynamic conditions were performed, including the following conditions:

a. varying seaward boundary salinity

b. effects of varying lateral, lower river diversions at La Reussite, Pt. a la Hache, and Bayou Lafourche

c. seasonal modification of basin freshwater base flow exclusive of Davis Pond and the other river diversions.

4.5.2 Methods

Three different analyses were carried out. First, we examined and characterized the salinity data acquired at three target locations. The new stations were compared with the long-term Louisiana Department of Wildlife and Fisheries (LDWF) stations at St. Mary's Point and

Grand Terre (Figure C.4-27). Mississippi River stage at Venice was also acquired, along with discharge at Baton Rouge.

Second, a sensitivity run was made using the “no marsh” model run in a dynamic mode for the April-May 1997 dataset in which boundary salinity was ramped from 15 to 25 ppt in the first month then reset to 15 ppt and ramped again to 25 ppt in the second month. Earlier results had indicated that such a ramp had no influence on target salinities when the model was run with the standard steady 5.75 mph wind.

Third, the observed 5 ppt data was evaluated each hour for any trend extending back two weeks (336 hours). Each segment was characterized by a mean salinity and a linear rate of change (+/-slope). Salinities changed during this pre-operations period primarily as a consequence of offshore salinity variations. If Mississippi River discharge and winds lower salinities offshore of Barataria Bay, the influence on target area salinities can be expressed in terms of an “equivalent” Davis Pond discharge. Based on the relationships developed in the Phase I report (Table C.4-5), these “equivalent” Davis Pond discharges give an understanding of the magnitude of the offshore influence.

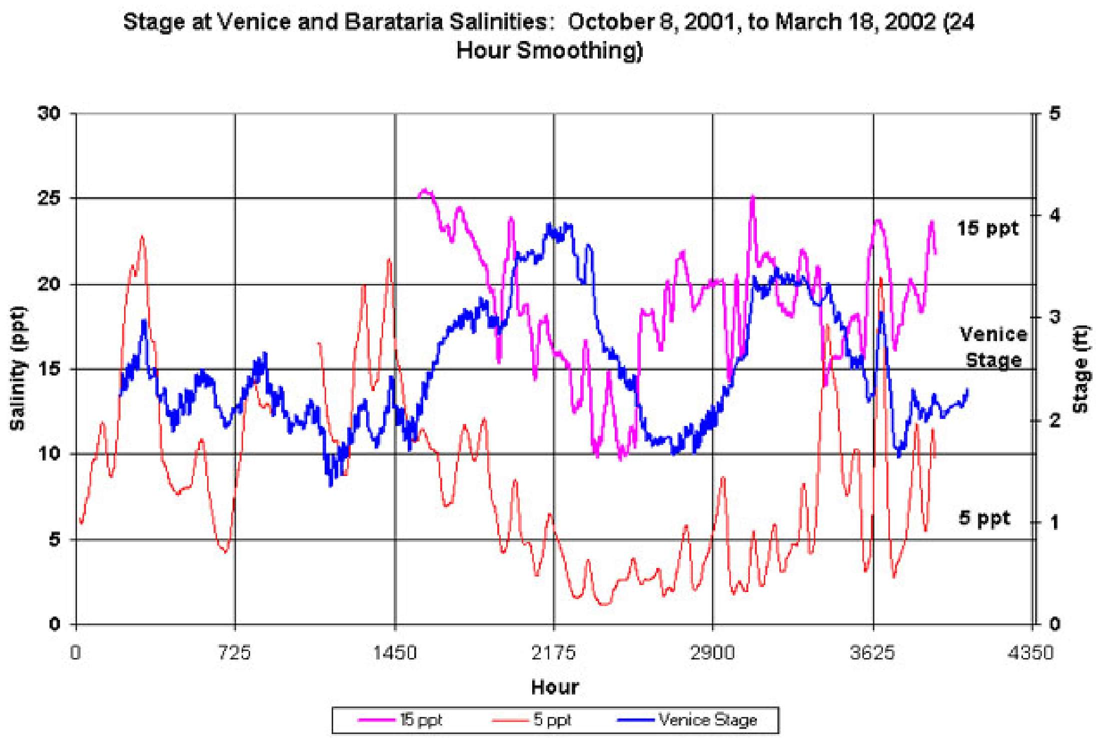

Figure C.4-26 Location of Davis Pond SRC stations and LDWF Salinity stations 315 (Grand Terre) and 317 (St. Mary’s Point)

Table C.4-9 Hourly Salinity Data at Target Locations: 12/8/ 2001 to 3/13/ 2002

(ppt)	B. Dos Gris U90006	Barataria WW at B. St. Denis U90004	5 PPT Mean	15 PPT Ford Line at Barataria WW
Maximum	24.50	25.40	23.95	26.30
Minimum	0.80	1.10	1.05	4.80
Mean	4.37	7.63	6.00	18.74
Standard Deviation	3.63	4.58	4.01	4.08

4.6 Results and Discussion

4.6.1 Salinity Data

The available salinity records at the two 5 ppt stations and the single 15 ppt station were obtained from the U.S. Geological Survey (USGS). All but the most recent 1.5 months of the same data were also available through LDNR. The 5 ppt stations have been operating since October 1, 2001, while the 15 ppt station has been in place since early December (Table C.4-9).

All of the stations varied over 20 ppt during the three months when synchronous data is available (December 8 through March 13). The 5 ppt stations exhibited slightly greater ranges than the 15 ppt station. Standard deviations were similar for all stations, indicating that 66 percent of all hourly values collected could be expected to occur within 3.6 to 4.6 ppt of the mean. It is important to note that the extreme high values experienced during this period were essentially the same at all stations and probably were similar to offshore values at that time. The two 5 ppt stations differed by over 3 ppt on average, with the higher values at the more central Barataria Bay Waterway station.

The relationship between the two target lines was best understood when the time-series were plotted after filtering out the tidal signal (Figure C.4-28). When the data was filtered in this way, it was easier to see the 5 ppt record as consisting of a relatively slowly changing baseline interrupted by departure events that raise salinity for a week or two. It could be seen that the baseline was generally within the monthly target range for October (0 to 725 hrs), was above it for the next two months (725 to 2175 hrs), and was within the target range for the last two complete months (2175 to 3625 hrs) (Table C.4-10).

At one point in late February (3500 hours), salinity at the 5 ppt line exceeded that at the 15 ppt station. Salinities at all stations approached 25 ppt just after the beginning of March (3630 hours). Variability of salinity at the 5 ppt stations is limited when salinities are low, as was true in January (2175 to 2900 hours), because values cannot drop below zero. On the other hand, it is not uncommon for salinity at the 5 ppt stations to rise or fall 10 ppt in less than a week.

Salinities in the target areas for the period of record were unaffected by the Davis Pond diversion or by exceptional rainfall events, but they did change, presumably in response to changes in salinity offshore. No hourly or other regular salinity data is collected offshore, but Mississippi River stage at Venice provides a proxy for river discharge to the continental shelf adjacent to the Barataria Basin passes (Figure C.4-28). It could be seen that salinities at both the 5 and 15 ppt lines dropped steadily during December (1450 to 2175 hours) as river discharge increased. From this point on, however, the apparently straightforward relationship between river discharge and Barataria Bay salinity broke down. As Dinnel (1984) showed, freshwater discharged to the shelf may stay in the vicinity of Barataria Bay in a relatively unmixed condition for some time, it may be quickly advected offshore, or it may mix rapidly with more saline waters. These responses depend on meteorological and density conditions.

Table C.4-10 Target Salinity Ranges by Month at the 5 ppt Salinity Line

Month	Salinity Range (ppt)
January	2 - 5
February	2 - 5
March	4 - 9
April	4 - 9
May	4 - 9
June	4 - 9
July	6 - 10
August	6 - 10
September	6 - 10
October	6 - 10
November	4 - 9
December	2 - 5

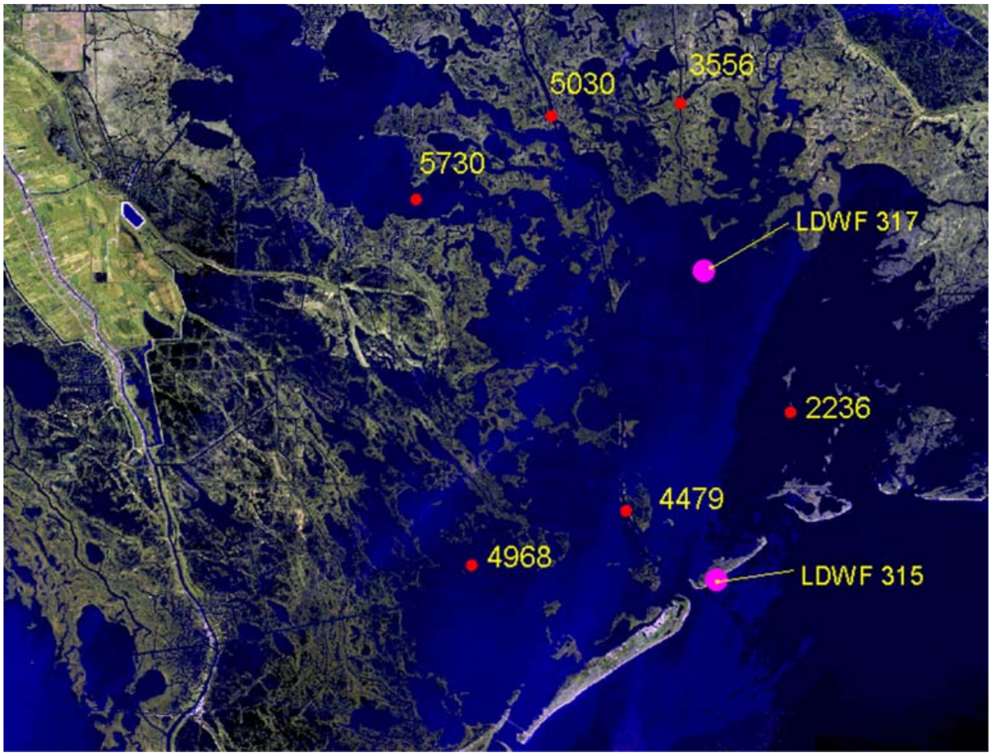

Figure C.4-27 Stage at Venice and Barataria Salinities

4.6.2 Model Runs

A sensitivity run was made using the "no marsh" model in a dynamic mode for the April-May 1997 dataset. The boundary salinity was ramped from 15 to 25 ppt in the first month then reset to 15 ppt and ramped again to 25 ppt in the second month. Results were plotted at the Barataria Bay Waterway site (N4479) on the 15 ppt line (Figure C.4-29). Results from previous work indicated that when such a ramp cycle was substituted for the standard constant 25 ppt boundary salinity, salinities in the target area were virtually unaffected. Except for the winds and tides, all other parameters were the standard set, with a constant 2,500 cfs Davis Pond diversion.

The sequence modeled was not unlike the fluctuations that naturally occur on the shelf off of Barataria Bay. The inclusion of realistic winds and tides made the modeled influence of boundary salinity change far more significant than in the static test. This was readily seen when the deviation in salinity at the boundary and at the 15 ppt line were plotted together (Figure C.4-30).

Boundary salinities in this test began at 15 ppt, with a 10 ppt deviation from the constant 25 ppt standard. This deviation then decreased linearly over the course of the month, so that the mean boundary salinity for the cycle was 20 ppt. An instantaneous 10 ppt drop in boundary salinity from 25 to 15 ppt was imposed at the beginning of the second month (May) so that the boundary deviation jumped to 10 ppt and the cycle repeated (Figure C.4-30).

Salinity at the 15 ppt line station did not respond for 8.6 days (207 hours) after initiation of the run. Although salinities then fell and later rose as a consequence of meteorological forcing during the remainder of the first month (Figure C.4-29), the boundary change caused a steady reduction in salinity within the bay (Figure C.4-30). The 10 ppt change at the boundary resulted in a maximum reduction of 4 ppt in the bay during the first month.

Despite the instantaneous drop in boundary salinity that was imposed at the beginning of the second month, salinity in the bay began a rise (*i.e.*, deviation from constant 25 ppt boundary drops). The reduction in boundary salinity at the beginning of the second month (746 hour) did not begin to reduce bay salinity until 12.7 days later (1050 hour). Although boundary salinities were rising toward 25 ppt throughout the second month, salinity in the bay continued to be reduced relative to the constant 25 ppt boundary run, reaching a maximum reduction of 5 ppt in the second month. This maximum occurred 5.8 days prior to the end of the test (1350 hour) when boundary salinities were within 2 ppt of the standard condition (25 ppt).

The model predicted that salinity response at the 15 ppt line lags change at the boundary by between 1 and 2 weeks, and that the magnitude of the response will be about half that experienced at the boundary. Salinity changes in the bay will often be out of phase with changes at the boundary.

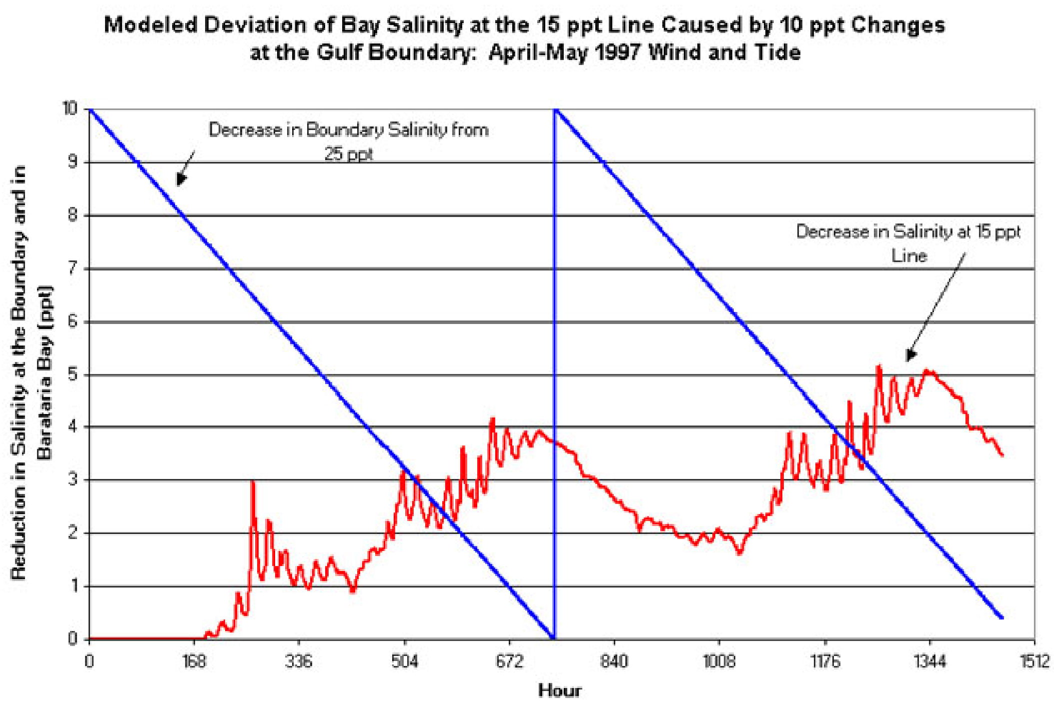

Figure C.4-28 Effect of Boundary Salinity at Barataria Bay Water Way at the 15 ppt line

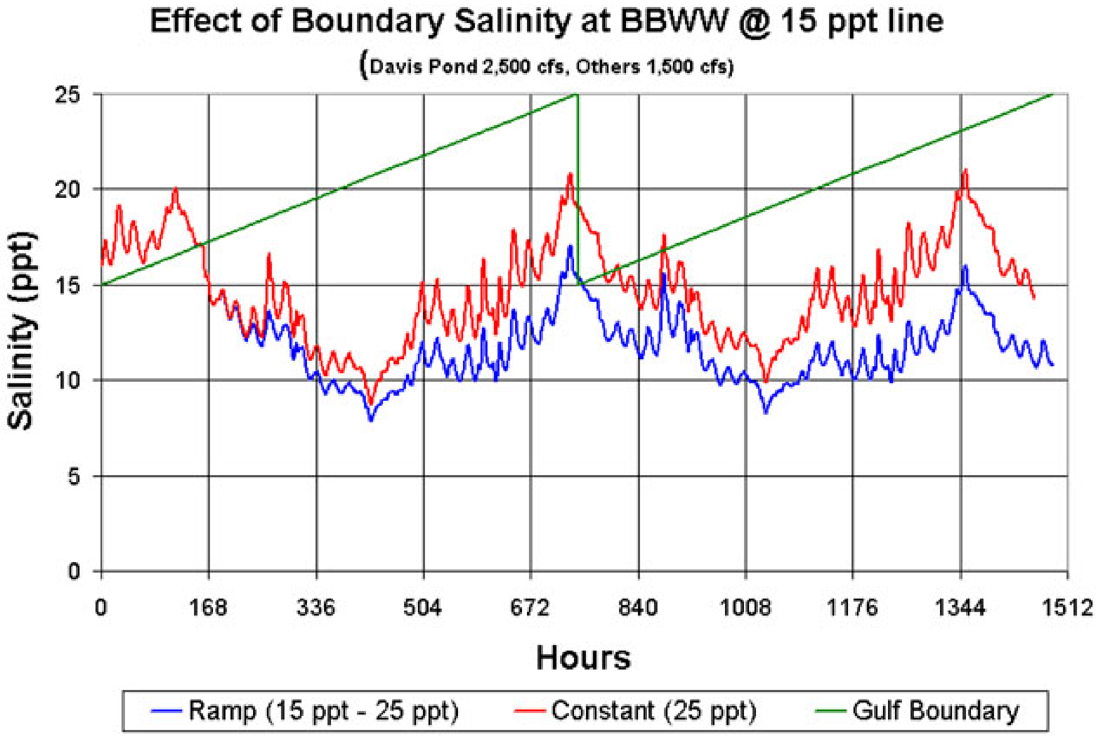

Figure C.4-29 Modeled Deviation of Bay Salinity at the 15 ppt Line Caused by 10 ppt Changes at the Gulf Boundary